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Transformative food value chains for local development

Edited by
Walter Odongo, Wolfgang Bokelmann, Silke Maria Stöber, Susanne Huyskens-Keil and Joanita Kataike

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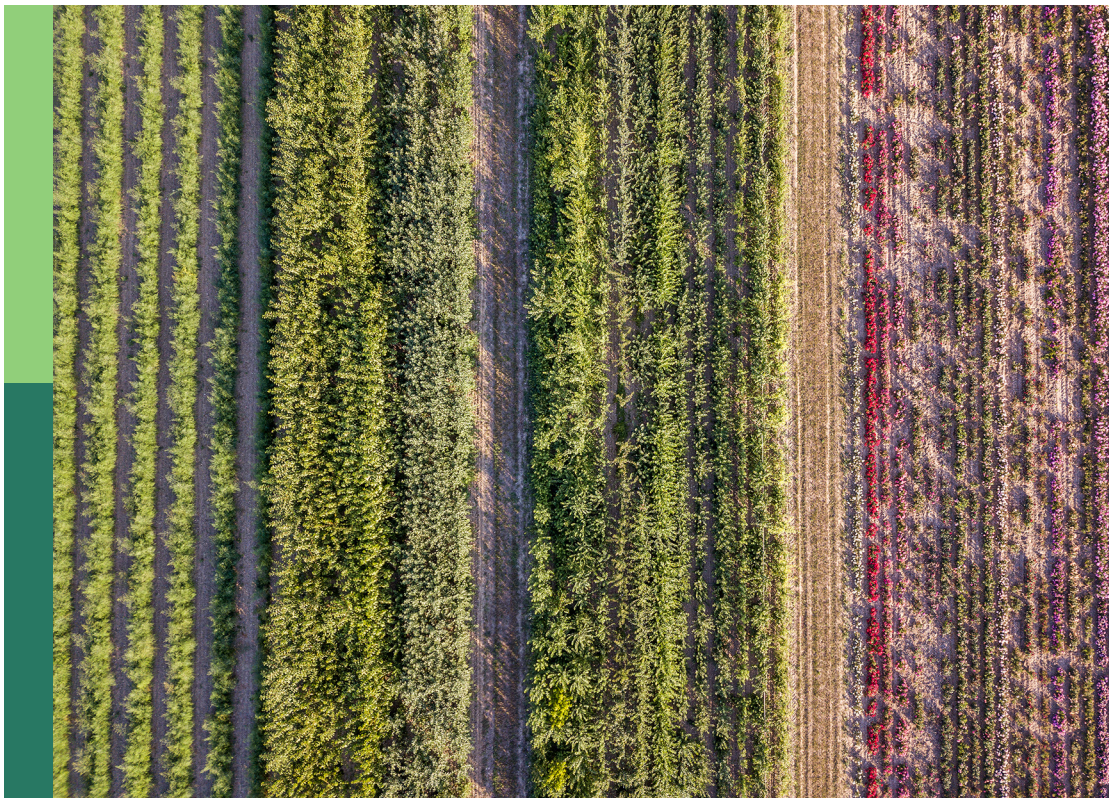

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Transformative food value chains for local development

Topic editors

Walter Odongo — Gulu University, Uganda
Wolfgang Bokelmann — Retired, Germany
Silke Maria Stöber — Humboldt-Universität zu Berlin, Germany
Susanne Huyskens-Keil — Humboldt University of Berlin, Germany
Joanita Kataike — Mountains of the Moon University, Uganda

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EDITED AND REVIEWED BY
Albie F. Miles,
University of Hawaii–West Oahu,
United States

*CORRESPONDENCE
Silke Stöber
✉ silke.stoeber@agrar.hu-berlin.de

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Editorial: Transformative food value chains for local development

Silke Stöber[1]*, Susanne Huyskens-Keil[2], Walter Odongo[3], Joanita Kataike[4] and Wolfgang Bokelmann[2]

[1]Centre for Rural Development (SLE), Faculty of Life Sciences, Humboldt-Universität zu Berlin, Berlin, Germany, [2]Albrecht Daniel Thaer Institute for Agricultural and Horticultural Sciences, Faculty of Life Sciences, Humboldt-Universität zu Berlin, Berlin, Germany, [3]Faculty of Agriculture and Environment, Gulu University, Gulu, Uganda, [4]Faculty of Business and Management Sciences, Mountains of the Moon University, Fort Portal, Uganda

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Editorial on the Research Topic
Transformative food value chains for local development

Introduction

Food value chain research and development has played a prominent role on the international development agenda for more than 20 years, forming the core of the framework for agri-food systems (Reardon and Minten, 2021). Over the years, the agri-food system has led to a remarkable increase in global food production and, thus, a reduction in hunger worldwide. At the same time, however, it has also led to a host of negative externalities, including increase in obesity and diet-related non-communicable diseases, poor working conditions and inadequate incomes for many farmers and workers throughout the value chain, deteriorating water quality, loss of habitat and biodiversity on land and in water, and accelerated climate change. Food does not reflect the true cost to human well-being and the environment of producing food in this way (Swinburn et al., 2019; Crippa et al., 2021; Ambikapathi et al., 2022; Barrett et al., 2022). The global food system has become largely dysfunctional in the face of the ongoing poly-crises—the economic crisis, the political crisis and the climate crisis (Carter et al., 2021; Höffler et al., 2023; World Economic Forum (WEF), 2023). As a result, food policymakers and scientists are calling for an urgent transformation of global food systems, a transformation to healthier, more sustainable, equitable and resilient food value chains (Anderson et al., 2021; IPES-Food ETC Group, 2021; Campbell et al., 2023; International Food Policy Research Institute (IFPRI), 2023; von Braun et al., 2023).

Transformative food value chains are crucial in rethinking and improving food systems. Despite the importance of agri-food value chains in transforming the food sector, there is a lack of understanding of how the complex interrelationships within the value chain work and what interventions can achieve the desired results. Generally, transformative value chains are characterized by their ability to bring about positive changes in various aspects of the food system, including social, economic, and environmental dimensions. They should have a positive impact on poverty reduction,

equality, social cohesion and food security in rural and urban areas and have a strong potential for greening (mitigating climate change and protecting biodiversity) (Anderson et al., 2021), as well as being just and fair [High-Level Panel of Experts on Food Security and Nutrition (HLPE), 2023; United Nations Children's Fund (UNICEF), 2023].

The COVID-19 pandemic has highlighted the importance of resilient and sustainable food value chains. It has tested the functioning of food systems and illustrated clearly the need to promote sustainable local value chains to ensure food security and nutrition. There is an urgent need to clarify how transformative value chains can ensure a reliable food supply for the population in rural regions. This raises the question of the resilience of local food systems (FAO, 2021a; Béné and Devereux, 2023). Local agri-food value chains are robust and often the only transmission belt that keeps resources and identity in vulnerable rural areas where food is produced (Jayne et al., 2019). In addition, domestic or regional chains can provide urban consumers with affordable, fresh, and healthy food. This value addition contributes also to food identity through local cuisine and meal cultures (Brückner and Caglar, 2016).

Transformative capacity and good governance are essential for food value chain coordination (Abel et al., 2019; Malabo Montpellier Panel, 2021; Resnick and Swinnen, 2023). While there is a considerable body of literature on smallholder farming participation and their inclusion in more coordinated value chains (Donovan et al., 2020; Diao et al., 2023), there is little evidence on the functioning and strengthening of the interlinkages between the different value chain actors. These interlinkages are a key pillar for promoting transformation, also in terms of innovations, technology and science (Badiane et al., 2023).

This Research Topic discusses examples of transformative value chains for sustainable local development. Informal, decentralized and neglected value chains can have a very strong transformative character. Therefore, this Research Topic specifically invited contributions on neglected and underutilized species (NUS) and underrepresented or informal actors. The latter are, for example, micro-entrepreneurs such as small street vendors, young agroecopreneurs or social farmers, i.e., actors that are not in the spotlight of conventional value chain research and development (Vorley, 2023). Neglected and underutilized species are wild or semi-domesticated plant species that receive little or no attention from agricultural science, plant breeding or agricultural politics (Kennedy et al., 2021). They do not appear in agricultural production or trade statistics or figure in regional or global value chains [African Orphan Crop Consortium (AOCC), 2015; Padulosi et al., 2021].

Transformative food value chains are an evolving area of research and practice. They offer opportunities to address the challenges faced by food systems and contribute to building more sustainable, equitable, and resilient food systems for the future. The overarching questions for this Research Topic on the transformation of food systems for local development are

- What theories and concepts help to develop transformative value chains?
- What adjustments must be made to research and development enabling local value chain actors to participate in transformative value chains?
- How do value chains of neglected and underutilized species differ from conventional value chains and contribute to local development?

Overview of contributions

The 12 articles in this Research Topic include theory and method articles, (mini)reviews, an opinion article, and original research articles. The research is from different countries, including Burkina Faso, Germany, Kenya, Malawi, Mali, Sudan, Uganda, and Zambia.

Mechri et al. developed a new value chain perspective by trading in strong sustainability, new resilience thinking, and systems thinking into the value chain development. They argue for a non-linear principles-based value chain approach based on agroecology, which is similarly advocated by the Coalition on Indigenous Peoples' Food Systems (FAO, 2021b).

The method of participatory hotspot analysis was field-tested in the dairy and groundnut value chain in rural Zambia by an interdisciplinary research team. Droppelmann and Müller invite value chain researchers and policymakers to apply this user-friendly transformative value chain assessment method as a starting point for developing transformative value chains. This tool can potentially discover sustainable innovations and identify actionable solutions.

Grohmann et al. analyse trust in its four dimensions and how trust is a prerequisite for coordination and cooperation in transformative food agri-value chains. The five case studies present sustainability-based agri-food value chains in Germany, coordinated via hybrid governance arrangements. The interaction of private, public and civil society actors also contributes significantly to agenda-setting and developing standards. The authors also reflect on building trust capacities that value chain developers might substitute if value chain actors lack such capacities.

The mediating effect of transaction costs, trust and performance in the tomato and soya bean value chains in Uganda is also addressed by Owot et al.. In addition to trust, the timely and accurate exchange of information between smallholder farmers and traders in northern Uganda positively affects value chain performance. Improving performance is critical to breaking out of the smallholder poverty spiral. Therefore, providing market price information systems is part of the development of transformative value chain systems.

African Indigenous Vegetables (AIVs) are gaining increasing attention in sub-Saharan Africa due to their climate resilience, contribution to smallholder income generation, and nutritional and health benefits in addressing the triple burden of malnutrition. Elolu et al. provide an overview of the AIV-specific value chain, characterized by high postharvest food losses, and document current postharvest management practices. They also highlight relevant new and innovative postharvest technologies and

associated challenges. They also suggest options for improving the benefits to AIV value chain actors to contribute to the sustainable transformation of nutrition-sensitive food systems.

Building the postharvest management capacity of baobab collectors, particularly women often excluded from training, would be an appropriate entry point for Cossam et al. to promote transformative baobab value chains in Malawi. Postharvest losses are exceptionally high during storage and marketing, so the authors recommend formulating standards for handling baobab products.

Sarr et al. examine factors influencing smallholder farmers' decision-making in adopting innovative food processing and preservation techniques for pigeon pea flour-based products, threshers, and dehullers in Tanzania. Training and awareness emerged as the most critical factors positively associated with adopting innovative processing and preservation techniques. In addition, the potential health benefits and time savings were the main drivers for smallholder farmers to adopt. Improving and expanding training programmes to be more inclusive could help create incentives and overcome adoption barriers.

Baobab is also a neglected species empirically analyzed in Sudan by Saeed et al. Baobabs' health and nutritional benefits are well documented (high in vitamin C and minerals such as calcium) and well known to parts of the population. However, the younger, better-educated and higher-income groups seem less appreciative of baobab pulp juice. This is a potential local product that could contribute to a transformative value chain in terms of agroforestry, healthy diets and income for poor rural women collectors. A re-awakening of consumer awareness would be an entry point.

Uckert et al. analyse consumer preferences for a local dried mango variety from Kitui District in Kenya, a poverty-stricken area dependent on agriculture, especially mango cultivation. The local development potential of Kitui mangoes has not yet been fully exploited. During the harvest season, mangoes flood the markets. The prices of the perishable mango are subject to fluctuations, and the profit is reduced. The study highlights the need for value addition through the drying of mangoes. It also shows how difficult it is to establish a new product in the local or export markets.

Kini demonstrates the vital role of neglected actors, such as women survival entrepreneurs and the bottom of the pyramid population, as actors in the food value chain in Burkina Faso. However, gender-responsive and inclusive value chains do not happen by themselves. Institutions and research are needed to promote social inclusion. The gender-aware inclusive business component and indicator set can guide value chain policymakers in this endeavor.

Agri-food value chains in humanitarian emergencies, conflict-affected settings and fragile states are a blind spot in research. FAO (2023) provides guidance on the food value chain upgrading in conflict-prone contexts. According to Baliki et al., developing transformative agri-food value chains in a conflict context is essential for food and nutrition security, mental wellbeing, and trauma reduction. They reveal that home gardening interventions in emergencies are low-hanging fruits, i.e., easy to implement, adaptable and widely promoted. However, there is little cross-learning between crisis-affected regions without a generalized theory of change and rigorous studies.

Similarly, Hänke et al. promote a two-pronged approach to food and nutrition security interventions in fragile contexts, addressing immediate and longer-term needs. Food systems transformation processes should be addressed immediately during emergency interventions. Multi-stakeholder dialogues have been successful interventions in Mali to build trust, strengthen social cohesion, and find structural solutions for ecological intensification and agriculture livestock integration.

Conclusion

The articles in this Research Topic highlight the diversity and complexity of interventions needed to promote transformative food systems. The studies also show that decentralized informal value chains are context-specific and cannot be easily applied in new contexts. This overview and list of interventions and applicable methodologies are not exhaustive. However, the recommendations provided in the articles are valuable starting points for further studies and research. Some issues haven't been covered at this stage, such as the importance of new business models pursued by the younger generation and their transformative value for local development. The specific role and contribution of informal institutions, such as traditional food markets or marginalized actors, such as survival entrepreneurs or local street vendors, has also not been fully addressed.

Future research to promote transformative value chains in decentralized informal settings should focus on a research set-up that links value chain actors in science-practice partnerships, such as living labs, co-research or transdisciplinary settings, with immediate impact on transformative processes and building transformative capacities. The importance of value-based systems thinking, sustainability innovations that do not compromise on social and environmental aspects, and easily replicable or low-barrier-to-entry solutions are essential to initiate tangible successes for the local population, especially the marginalized. Fragile contexts require special attention, as transformative value chains are crucial for local development, but fragile regions are disproportionately under-researched.

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EDITED BY
Wolfgang Bokelmann,
Albrecht Daniel Thaer-Institut füt Agrar- und Gartenbauwissenschaften, Germany

REVIEWED BY
Maria Rivera,
University of Evora, Portugal
Iván Roberto González-Puetate,
Universidad of Guayaquil, Ecuador

*CORRESPONDENCE
Janvier Kini
flavki3@gmail.com

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Gender-aware inclusive value chain: A theoretical perspective

Janvier Kini[1,2]*

[1]Institute for Health Sciences Research (IRSS)/National Centre for Scientific and Technological Research (CNRST), Ouagadougou, Burkina Faso, [2]Impact Research Institute, Dedougou, Burkina Faso

Achieving SDG5 requires an analytical and practical framework enabling a win–win participation of women with poor resources in gender-blind societies. Women with poor resources are mostly excluded from formal economic systems and face gender inequalities. In agricultural and food value chains, women are not equally included as men in highly attractive value chains, so they end up engaging in informal (less lucrative) agri-food activities alongside the value chains. However, the existing literature fails to design an adequate framework that efficiently addresses gender inequality and the poverty conditions of women in low-income countries, mostly gender-blind. This study contributes to filling this knowledge gap by proposing a gender-aware inclusive value chain from a theoretical perspective. For this purpose, we conducted a deep and extensive state-of-the-art study on value chain development and strategies over the past three decades. Two main types of value chains are drawn from this literature review: (1) conventional value chains, mainly exclusive or adverse, including the bottom of the pyramid populations and gender-blind; and (2) gender-aware value chains mostly focus on value chains that are controlled by women. Hence, the paper proposes a third type of value chains inspired by the Foucauldian perspective of human being: gender-aware inclusive value chain (GAIVC). This perspective considers a value chain similar to the human body in its functioning because the human body is composed of different organs that are autonomous but complementary to each other. GAIVC is also composed of different elements (actors/stakeholders, farms, storage, infrastructure, and so on) that should be complementary and non-competitive. From this perspective, it provides more opportunities for poor resource women to evolve into a non-discriminatory environment based on gender. It also breaks down the power relations between the chain actors, as they have to cooperate and avoid the chain from collapsing from within and outside threats. In this way, the sustainability of value chains is guaranteed, and all actors involved receive fair rewards from chain participation.

KEYWORDS

gender inequality, exclusion, poor resource women, value chain, human body

Introduction

Worldwide, women face unequal and exclusionary conditions in the agricultural (food) value chains. Although one-third of women's employment is in agriculture (including forestry and fishing), women are still largely overlooked by private and public sector actors and institutions in these value chains (UN Women, 2018; Kini, 2022). Women's positions in such value chains are largely influenced by gender inequality, thus hindering their empowerment [FAO (Food and Agriculture Organisation), 2011].

It urges the fight against gender inequality and women's exclusion, particularly in low-income countries. In this perspective, the sustainable development goal (SGD5) "*achieving gender equality and empower all women and girls*" is the very expression of the commitment of the international community to mobilize, on an equal basis, all the human resources, for the process of wealth creation to alleviate poverty and "leave no one behind" [UN (United Nations Department of Economic and Social Affairs), 2016]. In particular, leaving no one behind refers to the inclusion of specific vulnerable groups such as women, children, people with disabilities, elderly, small-scale farmers, fishers, indigenous people, migrants, and refugees in the development process' (van Tulder, 2018; Van Hees et al., 2019; Kini, 2022). Furthermore, SDG5 and SDG12 (inclusion in value chains) clearly show the relevance of considering these groups of people from the bottom of the pyramid (BoP) into the inclusive business component of inclusive development (Likoko and Kini, 2017).

However, the literature lacks a sound bottom-up approach addressing both gender issues and BoP inclusion in business and value chains (Kini, 2022). In particular, there is insufficient knowledge of an appropriate approach to address gender inequalities faced by resource-poor women and men in both the value chain and business. In addition, there is insufficient evidence on how business models for inclusiveness in urban food value chains affect the capabilities and functioning of women survival entrepreneurs (WSEs).

This study aims to fill these gaps in knowledge by providing a theoretical but empirically testable framework. For this purpose, the paper answers the question: How can value chains be conceptualized from a gender awareness and inclusiveness perspective?

The paper is organized as follows: Section "Critical review of the existing literature" presents the state-of-the-art literature on interlinked concepts such as value chain, inclusive business, gender awareness in business/entrepreneurship, capabilities and functioning, and firm-level economic wellbeing; Section "Theoretical perspective and discussion" answers the question while presenting the theoretical and analytical perspectives.

Critical review of the existing literature

To overcome the prevailing gender inequalities and constraints amidst resource scarcity, women's empowerment is viewed as a solution, as stated in SDG5. In particular, women's empowerment in value chains encompasses "business development interventions that focus on improving vertical linkages along the value chains (in production, processing, and trade functions) in order to improve their terms of participation" (Riisgaard et al., 2010, p. 6). Empowerment aims to "increase the capabilities of a target group in order to improve their terms of value chain participation" (Riisgaard et al., 2010, p. 7). However, empirical studies show that such business interventions tend to support organized groups instead of individuals (Riisgaard et al., 2010; Ros-Tonen et al., 2019). From this perspective, it is important to thoroughly review all the interlinked concepts, that is, value chain, business with the poor (inclusive business), and gender awareness in business and capabilities (at the group and individual levels), particularly for women in survival entrepreneurship (see "Institutions and entrepreneurship" and "Capability analysis framework: functioning, capabilities and agency").

Value chain

The literature between 1980 and 2019 shows a contested debate on value chains among scholars and practitioners. There are multiple definitions of value chains, ranging from simple to extended value chains (Kaplinsky and Morris, 2000). However, a common feature of these definitions is that a value chain describes the range of activities, from the production of goods and services to their final consumption [Freeman and Liedtka, 1997; Christopher, 2000; Kaplinsky and Morris, 2000; Mutua et al., 2014; FAO (Food and Agriculture Organisation), 2014, 2015; Bamber and Staritz, 2016; Bougdira et al., 2016]. On the one hand, some refer to the value chain definition as:

> *"A value chain refers to the full range of activities which are required to bring a product or service from conception through the different phases of production (involving a combination of physical transformation and the input of various producer services), delivery to final consumers, and final disposal after use"* (Kaplinsky and Morris, 2000, p. 4).

Others usually refer to the definition by FAO for whom: *"a value chain is the full range of farms and firms and successive coordinated value-adding activities that produce particular raw agricultural materials and transform them into given food products that are sold to final consumers and dispose after use, in a manner that is profitable throughout as broad-based for society,*

and does not permanently deplete natural resources" [FAO (Food and Agriculture Organisation), 2014, p. 6].

The first definition of the value chain covers all economic sectors, whereas the second focuses on the agricultural sector (including agribusiness). This is likely because access to food is one of the most crucial issues worldwide, particularly in developing countries (FAO, IFAD, UNICEF, WFP, and WHO, 2019). Value chain has also been defined as an analytical and operational model (Safari, 2011; Agri-ProFocus, 2014). Such a model takes the idea that "a product is rarely directly consumed at the place of its production as its starting point. Instead, the product is transformed, combined with other products, transported, packaged, and displayed until it reaches the final consumer. In this process, the raw materials, intermediate products, and final products are owned by various actors who are linked by trade and services, whereby each actor adds value to the product" (Safari, 2011, p. 18; Agri-ProFocus, 2014, p. 9).

This paper adopts this definition, as it is applicable to all types of value chains, including food commodities, textiles, mobile phones, and so on. Two main strands of value chain literature can be identified: conventional value chain literature, which is critiqued to be largely poor-exclusive and "gender neutral," and gender-aware value chain literature.

Conventional value chains

Conventional value chain literature is embedded in two main positions. The first position considers value chains from an agile manufacturing approach [Freeman and Liedtka, 1997; Zhang et al., 2002; Roper et al., 2008; Singer and Donoso, 2008; FAO (Food and Agriculture Organisation), 2014; Tarafdar and Qrunfleh, 2016]. The related body of literature focuses on strategic alliances within the chain and partnerships to achieve speed and flexibility in production and marketing processes. Therefore, responsive and networking strategies between chain actors feature centrally in value chain analysis and development.

The second position considers value chains from a governance and management perspective (Carter and Rogers, 2008; Seuring and Müller, 2008; Sarkis et al., 2011; McDonald, 2016; Mishra et al., 2016). This approach proposes the use of information and communication technologies to (better) connect stakeholders in the chain. Furthermore, this innovation-based approach ensures that goods and services are delivered at home and in time, while recording the traceability of their flows over the chain (Roper and Arvanitis, 2012; Bougdira et al., 2016; McDonald, 2016). Interestingly, producers and consumers do not need to physically meet each other because the chain is formally organized. Only the price and information on the quality of the product provided by the supplier are sufficient for the demander to purchase. However, traceability can be challenging depending on the length of the value chain. Indeed, with regard to the length of a value chain, the literature distinguishes between long value chains [Bolwig et al., 2010; DANIDA (Danish International Development Agency), 2010] and short value chains (Marsden et al., 2000). A long value chain involves many intermediaries from various locations. This requires looking into the horizontal and vertical linkages existing in the chain as well as the impact of intermediaries' activities on the price, quality, and availability of products (Bolwig et al., 2010). In this regard, it may be difficult for consumers to have clear traceability of the products they purchase (Marsden et al., 2000). By contrast, a short value chain represents horizontal and vertical integration within the value chain (Marsden et al., 2000), which allows the producer to reach the consumer directly and quickly with few (or no) intermediaries. Furthermore, the control of information and knowledge shared between stakeholders (producers and consumers) and exchanged goods and services' traceability, among others, are the core elements in the short value chain (Marsden et al., 2000). Two main weaknesses can be identified from this conceptual and theoretical debate on value chains. The first weakness is neoliberal underpinning, which implies a market-oriented focus on profit maximization and individual gains. This mostly overlooks power differences within value chains, particularly the disenfranchised position and role of small producers and the poor (Hickey, 2010). The formal governance context is presumed to have been largely taken for granted. This limits the applicability of this literature to developing country contexts where formal structures, rules, and regulations are often not in place, informality is high, and collaborative arrangements among value chain actors who are resource-poor are a common strategy. The second weakness is that the early value chain literature is not gender-aware or even attentive to broader power differences that structure socioeconomic relations within and around the value chain. Hence, value chains are seen as "gender-neutral," assuming equal access and control over different nodes and relationships in and outside the value chain by women and men as if they participate under similar conditions.

Gender awareness in value chains: Focus and limitations

The literature on gender-aware value chains has increasingly emerged in the last 20 years, focusing on integrating gender inequalities faced by women into the conceptualization and theorizing of value chains [USAID (US Agency for International Development), 2009; Riisgaard et al., 2010; Boodhna, 2011; Coles and Mitchell, 2011; Farnworth, 2011; Farnworth et al., 2015; Laven and Pyburn, 2015; FAO (Food and Agriculture Organisation), 2016; Ros-Tonen et al., 2019]. First, a gender-aware value chain approach analytically increases the visibility of the roles of men and women in various segments of the chain as well as gender-specific barriers to entry and opportunities for participation and development. For instance, some barriers include low access to markets due to the

cultural seclusion of women (Farnworth, 2011; Waithanji et al., 2013), reduced income control by women caused by increased commercialization (Njuki et al., 2011), and women's lack of access to technology [FAO (Food and Agriculture Organisation), 2011]. These barriers determine the level of entry into value chains and the capacity of an actor to compete with others. This enhances our understanding of how different value chains function and the results for different actors along the chain.

Second, gender dynamics also play an important role in understanding value chain strategies [FAO (Food and Agriculture Organisation), 2011; Farnworth, 2011; Njuki et al., 2011; Waithanji et al., 2013]. Gender dynamics refers to the relationships and interactions between women and men [USAID (US Agency for International Development), 2009]. These dynamics can be captured by analyzing the scale and participation of (groups of) women and men in the chains (Coles and Mitchell, 2011). At the household and community scale, gender dynamics shape individual and community interactions, which in turn influence the value chain. That is, household and community cultural norms for men's and women's roles influence individuals' behavior, so that their interactions in a value chain also affect the dynamics of this value chain. Moreover, with regard to participation and decision making, gender dynamics influence value chain governance and management. That is, in gender-neutral societies, the governance system is dominated by men who lead decision-making because they are more powerful than women. This literature on gender-aware value chains bring novelty to value chain theory in the sense that it puts at the heart how cultural norms shape the power relationships between both. By focusing on these gender issues, this literature values the specific position and roles of women in value chains and points out the restricted level of women's inclusion on an equal basis compared to that of men.

However, even if this body of literature is relevant to addressing the specific context of gender inequality in value chain participation, it does not address the resource constraints and informality conditions of the women and men involved in those value chains. Moreover, this study does not specifically consider the case of the bottom of the pyramid (BoP) population in value chains. The consideration of the BoP population in value chains from a gender-aware perspective requires an inclusive approach. The reason for considering the BoP population is that, to achieve the SDGs, all policies, development interventions, and businesses should leave no one behind. Hence, an appropriate approach addressing gender inequalities faced by resource-poor women and men in value chains is the main gap that still needs to be filled. To achieve this, this study holds that a more inclusive approach to value chain theory may be a solution, and this is how it contributes to inclusive development.

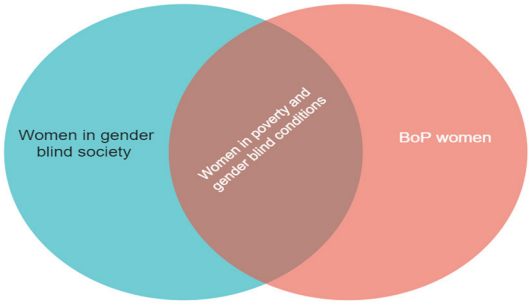

FIGURE 1
The scope of Gender-aware Inclusive Value Chain. Source: The Author.

Inclusive approach to value chains

The literature sheds light on the possibility of a more inclusive approach to value chains. This perspective places human beings at the center and integrates gender issues and BoP women's inclusion, as shown in Figure 1.

This figure indicates the scope of the inclusive approach to value chains, which is rooted in a gender sensitive interpretation of Foucault's "archaeology of knowledge" in human sciences which studies: *"man in so far as he lives, speaks, and produces. He is a living being that grows, that has functions and needs, that sees opening up a space whose movable coordinates meet in him, in a general fashion, his corporeal existence interlaces him through and through with the rest of the living world, since he produces objects and tools, exchanges the things he needs, organizes a whole network of circulation along which, what he is able to consume flows, and in which he himself is defined as an intermediary stage, he appears in his existence immediately interwoven with others; lastly, because he has a language, he can constitute a whole symbolic universe for himself, within which he has a relation to his past, to things, to other men, and on the basis of which he is able equally to build something like a body of knowledge (in particular, that knowledge of himself…)"* (Foucault, 1972, p. 383).

Analogical to this definition, this study sees a value chain as a living process or system that lives, speaks, and produces. As such, the value chain grows, has functions, and needs; it is like a system defined by Bressy and Konkuyt (2008), but different because it is not only profit-oriented, nor solely about marketorientation and competitiveness. Instead, such a system operates to allow the entire chain to live, speak, and produce over time and space. Consequently, the value chain performs well if each component plays its role in a durable manner. This makes a distinction between the living performance (existing aspect), communicative performance (speaking aspect), and productive performance (producing aspect) of the system.

First, a value chain lives when its existing components exist—physical elements, including stakeholders (people) and other physical entities (infrastructure, production sites,

warehousing, shops, roads, equipment/materials, and livestock). In a healthy human body, all of these (autonomous) elements interact to keep the body alive and grow over time without any competition among and between themselves; they cooperate and unify. This assumes that all value chain elements are as important as those in the human body because none of them can be excluded or marginalized by others for any purpose; they are individually necessary to allow the entire value chain to be alive and operating. Thus, stakeholders individually and collectively determine the other components of the chain and influence the shape and dynamics of the value chain. Therefore, stakeholders can be assimilated into the nervous system which orders and regulates the tasks of the other components in the value chain. Hence, stakeholders' socioeconomic characteristics (individual and collective agencies and capabilities) significantly influence the shape and dynamics of the value chain. Finally, the process of growth or development in the value chain is determined by each component's capacity to ensure its own function as a necessary condition to keep the value chain "alive."

Second, just as a human being speaks, value chains also speak. A value chain's speech refers to the communication system used inside and outside; a value chain has an internal and external environment that communicates over time. Internal communication is similar to how a human body's components communicate with each other, thus creating an interlinked communication and information system. For example, the information and networking systems used by stakeholders in the value chain are information, services, and service flows between similar components and other components of the chain. The value chain also communicates with its external environment, comprised of other value chains and natural environments (small scale and/or large scale) related to climate change risks or pollution concerns. Therefore, this assumes that sustainable internal and external environments positively influence communicative performance, as well as gains from value chain participation.

Third, just as a human being produces to meet its needs and ensure its functions, the value chain is assumed to produce goods and services. Functions refer to all the activities in the value chain. Porter (1985) identified five primary functions in a chain and four support activities in the human-centered approach to the value chain. (a) The primary functions of the value chain are inbound logistics, operations, outbound logistics, marketing and sales, and services, whereas the support functions are procurement, technology, human resource management, infrastructure, and culture (Porter, 1985). (b) The value chains' needs refer to Maslow's theory on living beings' needs under the "hierarchy of basic needs" (Maslow, 1943). However, instead of considering all five basic needs identified by Maslow, the physical survival needs and physical safety needs stand to fit better in the approach, as they are preconditions for other needs in a human being's life. Physical and survival needs refer to the need for resources (e.g., human, natural, informational, and communicative resources) that feed the value chain and allow it to survive and perform in both internal and external environments. Moreover, physical safety needs are related to keeping the value chain safe in its external environment. In other words, how to maintain the value chain free of dangers and threats from the other value chains in its external environment (e.g., competition from the other value chains) and from natural environment risks, particularly climate change concerns (pollution, droughts, and floods).

However, this inclusive approach to value chains is complex, as it requires a large amount of information and data, as well as techniques and tools to analyse them. Indeed, the longer the chain, the more data are required. For example, when the chain is long, there are many intermediaries at the different nodes of the chain (e.g., transport, information, and communication service providers) that are widely spread in space (Bolwig et al., 2010). Therefore, obtaining information and data from these types of stakeholders is costly in terms of time and financial resources. Some specific information, such as quality goods and services, may not be traceable; therefore, the accountability of actors in the chain is sometimes difficult to establish. A costly investment is required to make goods and services traceable in a long value chain (Bougdira et al., 2016). In contrast, in a short value chain, there are fewer or no intermediaries involved, thus facilitating knowledge and information sharing among low-income stakeholders in the chain, and traceability information can be low cost (Marsden et al., 2000). Therefore, the approach assumes that the shorter the length (fewer intermediaries) of the value chain, the more gender-aware and inclusive it is, and the higher the expected outcomes (i.e., material and non-material gains). Hence, the concept of a short value chain fits better in the context of this research, as women's empowerment in such a value chain is much more relevant than in a long chain (which hides more disparities because of intermediaries and environmental costs (e.g., pollution] in goods transportation). Moreover, the dynamics of short chains in terms of temporal evolution may be more deeply analyzed compared to a long chain, as stakeholders on the supply side are not numerous in a short chain. In contrast, the space side of the short-value chain fundamentally depends on context or location. The case at hand concerns (peri) urban areas.

From the gender-aware and inclusive perspective of value chains, it is worth examining the literature and drawing on the inclusive business approach that fits in.

Inclusive business

The concept of inclusive business (IB) has been anchored in the debate between two epistemological stances: the resource-based approach and the cultural cognitivism approach (Likoko and Kini, 2017). The resource-based approach examines the

firm's potential resources or internal capacities, which are the basis of its competitive advantage (Wernerfelt, 1984; Sullivan, 1998). Therefore, the firm performs when it is able to combine its scarce resources efficiently to achieve maximum output (profit maximization).

However, this approach appears to be exclusive to the poor and creates more inequalities among populations, according to the cultural cognitivism view of the firm that tries to address this limitation (Penrose, 1959; Nooteboom, 2006). Indeed, the latter approach calls for the inclusion of local populations and communities in doing business (Sullivan, 1998), in such a way that inclusive business models must aim to include low-income communities into a business value chain by addressing stakeholders' needs and perceptions, and adjusting the product to the target market (Golja and PoŽega, 2012).

Unfortunately, the challenge of inclusive business is related to its operationalisation. Divergent positions from practitioners and scholars are found in the literature, even if both recognize that inclusive businesses have to target low-income and marginalized populations (Likoko and Kini, 2017). On the one hand, scholarly discourses on inclusive business support the inclusion of BoP populations into business to alleviate poverty (Prahalad and Ramaswamy, 2004; London and Hart, 2011). For example, one school of thought claims that inclusivity involves the creation of a positive development impact using economically viable business models that do not lead to negative ecological impacts in the short and long terms (Wach, 2012). Another definition claims that the departure of the inclusive business approach from an exclusive focus on profit generation gives it the potential to supersede development programs (Wach, 2012). As such, inclusive business is seen as "sustainable business solutions that go beyond philanthropy and expand access to goods, services, and livelihood opportunities for low-income communities in commercially viable ways" (Bonnell and Veglio, 2011, p. 2). Another group of scholars defined inclusive business as accounting for human dignity or human rights considerations in businesses through (a) protection against third-party abuse, (b) respect for human rights, and (c) access to legal remedies by local people (Ioannou and Serafeim, 2012; Sopov et al., 2014). Thus, a business model is considered inclusive if it is durable, equitable, effective, adaptable, and credible.

On the other hand, most inclusive business models from practitioner communities focus on the inclusion of the BoP (UNCTAD, 1999; UNDP, 2010; Dietrich and Bauer, 2013; Naguib et al., 2013; Petkoski, 2014; Likoko and Kini, 2017), as the poor are employees, producers, business owners, and/or consumers of affordable goods and services (UNDP, 2010; Naguib et al., 2013). From this perspective, IB is considered a business that integrates smallholders/small producers/employees into markets with mutual benefits for the poor and the business community while enabling the poor to move out of poverty and establish food security. Such inclusion is not just a company's responsibility, but also the responsibility of producers, the public sector, buyers, and NGOs [FAO (Food and Agriculture Organisation), 2015].

From these discourses on inclusive business, both practitioners and scholars (Likoko and Kini, 2017), inclusive business must be connected to inclusive development (Gupta et al., 2015). As such, the related theoretical stance rejects the idea of the firm or corporation as the main driver of business in the sense that it only includes the BoP population as raw material suppliers, workers, or simple input distributors (Likoko and Kini, 2017); however, it shares the human rights approach where the BoP population benefits win–win businesses and is not adversely included (Hart, 2007; Sopov et al., 2014). Therefore, inclusive businesses should aim to provide sustainable livelihoods (Naguib et al., 2013) to companies and poor communities, and companies should not be the only drivers of these business models [FAO (Food and Agriculture Organisation), 2015]. In addition, such business models tend to be less attractive to capital investors because most are risk-averse [Bannick et al., 2015; FAO (Food and Agriculture Organisation), 2015], thus, there is a need for an alternative funding mechanism to guarantee the sustainability of such a business model.

Gender awareness in business

The understanding of inclusive business in section "Inclusive business" is still general, as it does not consider the specific issues of gender inequality between men and women in doing business or starting a business first. Indeed, the literature shows that men and women entrepreneurs do not face the same realities. The current section fills this knowledge gap.

Gender in business

In business, gender refers to the roles, behaviors, activities, and attributes that a given society at a given time is appropriate for men and women. In addition to the social attributes and opportunities associated with being male and female and the relationships between women and men and between girls and boys, gender also refers to the relationship between women and men. These attributes, opportunities, and relationships are socially constructed and learned through socialization processes. They are context- and time-changeable. Gender determines what is expected, allowed, and valued in a woman or a man in a given context' (UN Environment, 2019, p. 695).

Taking a gender-aware approach to studying inclusive businesses has five implications. First, it questions the dominance of profit maximization as the sole motive for engaging in business. For example, considering gender in entrepreneurship ends the definition of entrepreneurs as "rational money-driven" individuals pursuing financial profit maximization (West and Zimmerman, 1987; Vossenberg, 2016).

Aside from profit incentives to engage in business, social-relational and psychological aspects of wellbeing (Pouw and Kini, 2016; Pouw, 2017), particularly self-esteem, are needed for social relations or to feel socially useful.

Second, it sees entrepreneurs as decision makers with an unbalanced distribution of "powers, resources, and responsibilities for paid and unpaid work" (Vossenberg, 2016, p. 11).

Third, it considers entrepreneurs as "socially embedded human beings who have a gender, body, class, age, family, religion and ethnicity, and live within a specific historical, social, economic and geographical context" (Brush et al., 2009; Vossenberg, 2016, p. 12). As such, looking through a gender lens shows that it is not just microeconomic factors that affect the opportunities for women to participate in business (Vossenberg, 2016, p. 12), but also macro factors such as institutions (Acemoglu and Robinson, 2012; Sen, 2015), and "different types of women entrepreneurs can have different practical or strategic needs" (Vossenberg, 2016, p. 12).

Fourth, a gender lens shows how social identity, including age, gender, health, and religion, can influence entrepreneurs and account for inequalities (Vossenberg, 2016, p. 12).

Fifth, a gender-aware perspective on inclusive business distinguishes at least two types of entrepreneurs: survival and growth-oriented entrepreneurs (see Vossenberg, 2016), or necessity and opportunity entrepreneurs (Fuentelasz et al., 2015; Zoumba, 2018). On the one hand, survival or necessity entrepreneurs are (1) those with little or no intention/motivation to grow or expand their businesses (Hurst and Pugsley, 2011); (2) involved in low-quality or subsistence entrepreneurial activities motivated by necessity (Schoar, 2010; Fuentelasz et al., 2015); and (3) creating jobs for their owners (Reynolds, 2010; Hurst and Pugsley, 2011). They struggle to balance their business with unpaid care responsibilities and are challenged to earn enough income to satisfy their households' needs (Karim, 2001; Berner et al., 2012; Vossenberg, 2016). The main reason for staying survival entrepreneurs (SE) is that they do not have the capabilities, freedom, or expand their business beyond the limits of their own labor and management capacities (Berner et al., 2012; Vossenberg, 2016). Thus, such entrepreneurial activities provide few benefits to society as a whole (Baumol, 1990). However, such entrepreneurs represent a significant part of business; for example, 31 and 37% of start-ups (nascent businesses) recorded in Ghana and Nigeria, respectively, were necessity entrepreneurs and had no intention of growing their businesses (Xavier et al., 2013, p. 60). Consequently, entrepreneurship development policies often fail because they fail to acknowledge the fact that surviving entrepreneurs do not necessarily have a growth ambition (Vossenberg, 2016). On the other hand, growth-oriented or opportunity entrepreneurs are (i) engaged in more productive and transformational entrepreneurship; (ii) tend to be more innovative by creating new products, processes, and jobs; and (iii) extend the tax base for the government (Sobel, 2008; Hurst and Pugsley, 2011; Fuentelasz et al., 2015). A rich body of literature provides the underlying factors enabling a business to grow (moving from survival-to growth-oriented), which are embedded in the theory of institutions (North, 1990) and the politics of inclusive development (Sen, 2015). According to this literature, the fundamental determinants of an enterprise's growth are political (regulatory), such as institutions that encourage businesses (North, 1990; Acemoglu, 2009; Khan, 2010; Sen, 2015).

Institutions and entrepreneurship

Entrepreneurship and business evolve within an institutional environment that is conducive to business. "Institutions refer to the regularized patterns of interaction by which society organizes itself: the rules, practices and conventions that structure human interaction" (UN Environment, 2019 p. 698). Institutions can also be "the rules of the game or, more formally, the humanly devised constraints that shape human interaction" (North, 1990, p. 3). As such, institutions can potentially shape societal choices with respect to technology and (capital) accumulation (Acemoglu, 2009). Thus, institutions encompass law, social relationships, property rights and tenurial systems, norms, beliefs, customs, and codes of conduct, and as such, they can be "formal (explicit, written, often having the sanction of the state) or informal (unwritten, implied, tacit, mutually agreed and accepted)" (UN Environment, 2019, p. 698). In the entrepreneurial debate, strong evidence supports the notion that institutions have an important impact on the entry, survival, and growth of enterprises (Eesley et al., 2018; Chowdhury et al., 2019).

First, institutions affect the quality and quantity of entrepreneurship in four layers (Chowdhury et al., 2019). The first layer comprises the informal institutions of a country, which are anchored in society and include habits, customs, and beliefs (Bruton et al., 2010; Eesley et al., 2018; Chowdhury et al., 2019). Indeed, informal institutions first influence individuals' "choice to be entrepreneurs, the industries and sectors they will enter, and the appropriate strategies they will consider" (Eesley et al., 2018, p. 395). In contrast, "norms of the various stakeholders" expressed in terms of "strategies" adopted influence the firms (Pache and Santos, 2010; Eesley et al., 2018, p. 395). Informal institutions play an important role, particularly when institutional voids occur (Mair et al., 2012). This is the case, for example, when there are contestations on right actions resulting in the "formation of informal norms and sanctions that allow the development of functioning markets" (Eesley et al., 2018, p. 395).

The second layer comprises the formal regulatory institutions of a country (Eesley et al., 2018; Chowdhury et al., 2019), which can reduce the uncertainty and risk associated with entrepreneurial activity (Smallbone and Welter, 2012). A rich body of literature shows evidence of the effects

of formal institutions embedded in the rules of law. Indeed, formal institutions affect entrepreneurship, notably the quantity of entrepreneurship (North, 1990; Eesley et al., 2018). For example: (1) simplifying the "procedures for obtaining licenses and permits to start new firms increases venture formation" (Klapper et al., 2006; Eesley et al., 2018, p. 394); (2) a decrease of the government's regulation burden engenders an increase of entry rates in business (Levie and Autio, 2011). However, formal institutions can negatively influence entrepreneurship if the cost of complying with regulations is high (Klapper et al., 2006). For example, complying with environmental taxes leads to the environmental orientation of entrepreneurial ventures, which may not be affordable for certain poorer entrepreneurs (H?risch et al., 2017).

The third layer of institutional influence is governance, which drives resource allocation in a country (Chowdhury et al., 2019). For example, some authors have shown that entrepreneurial activities are highly sensitive to changes in government stability, internal and external conflicts, ethnic tension, control of corruption, and rules of law (Gholipour and Tajul, 2012).

The last layer of institutional influence is resource allocation, jointly determined by the first three layers (Chowdhury et al., 2019). For example, the "quality of the institutional environment influences an entrepreneur's attitudes, motives, and ability to mobilize resources" (Reynolds, 2010; Chowdhury et al., 2019, p. 54); and "shapes the rules of the game, which in turn affects the quality of entrepreneurship" (McMullen et al., 2008; Chowdhury et al., 2019, p. 54–55). Second, many studies have shown that institutions are interactive and dynamic over time (Eesley et al., 2018; Chowdhury et al., 2019). This suggests that focusing on interactions of informal institutions tends to be stronger or more influential compared to formal institutions in terms of the quantity of entrepreneurship. Indeed, a change in formal institutions aimed at boosting entrepreneurship can be a failure due to "the effects of informal institutional forces to seek legitimacy" (Eesley et al., 2018, p. 395). Informal institutions can shape firm behavior if they do not fit with formal institutions because "the normative and cultural-cognitive elements provide the social framework within which entrepreneurship occurs" (Eesley et al., 2018, p. 396). In addition, informal institutions are extremely influential because, instead of "being imposed on individuals by policymakers, they are 'taken-for-granted' social and cultural norms that are embedded in continuing social relationships" (Tolbert and Zucker, 1983; Eesley et al., 2018, p. 396). Third, many studies showcase that entrepreneurship in turn significantly influences the institutions (Chowdhury et al., 2019), both in the short and long-term (Samadi, 2019), in regard to the "level of economic development of countries" (Chowdhury et al., 2019, p. 55; Samadi, 2019). The main conclusion of these studies is that "entrepreneurs are an important source of institutional changes, especially in developing countries" (Samadi, 2019, p. 3). For example, as "institutions influence individual behavior, over time entrepreneurs also take the initiative to change the institutions that are beneficial to them' (Chowdhury et al., 2019, p. 54). Thus, this theoretical debate concludes on the 'bidirectional' relationship between institutions and entrepreneurship (Chowdhury et al., 2019, p. 53), particularly in "innovation-driven countries and in the long run" (Samadi, 2019, p. 11).

Despite the relevance of this debate, it does not clearly show what and how institutional factors drive growth orientation at both firm and country levels, particularly when adopting a gender lens for entrepreneurship in low-income countries. Sub-section "Gender awareness and inclusiveness in business" intends to address this point.

Gender awareness and inclusiveness in business

Integrating gender awareness and inclusiveness is challenging and is tied to the operationalisation of inclusiveness. Some authors define an inclusive business as one that is innovative, credible, affordable (equitable), adaptable, and viable (efficient) (Sopov et al., 2014; Likoko and Kini, 2017). This study uses the operational definition of inclusive business to challenge the integration of gender awareness. First, a business is innovative if it brings new ideas and creates opportunities by removing economic, social, ecological, and geographic barriers (Likoko and Kini, 2017). Thus, it enhances the social and economic wellbeing of disenfranchised members of society (George et al., 2012), and maintains local ecosystems (Adams et al., 2016) by promoting sustainable value creation (Hart et al., 2003). As such, innovation is dynamic and based on learning processes which bring together scientific and local knowledge (Odame, 2014). Some authors consider a business to be innovative if it is technologically simple in terms of both tools and practices. For example, Sopov et al. (2014) showed that incremental technologies built on customary wisdom and practices can easily be assimilated into communities (Sopov et al., 2014). In contrast, other authors believe that this view of innovation is restrictive, as innovation is only seen in terms of technological change in products and processes (Blake and Hanson, 2005). For the latter, this view of innovation is tied to export-based theory in the neoliberalist development model, where, for example, cities are only considered as production centers for products exported to the areas outside for further distribution and consumption.

From an operational perspective, integrating gender awareness as an innovative dimension of inclusive business means creating opportunities for disenfranchised (i.e., poor) women survival entrepreneurs (WSEs) from poor communities, addressing existing economic, social, ecological, and geographic barriers, and creating sustainable value, thus enhancing their wellbeing. In particular, such a business focuses on breaking

gender barriers and ensures that the tools and practices used are built on customary wisdom. It also considers the local scale (e.g., urban informal settlements) by capturing the place-specific nature of a market that enables the creation of a successful business, in accordance with Blake and Hanson (2005).

Second, a business is credible if it offers real benefits in the form of stable and long-term commercial relationships that can be tracked and reported (Sopov et al., 2014). In other words, such a business builds up strong and stable commercial connections both vertically and horizontally in the value chain in which they evolve. The business is also credible when these commercial relations are gender-aware and if no gender barrier exists which makes (individual) WSEs powerless among the stakeholders.

Third, a business can be affordable if it is equitable and effective (Sopov et al., 2014). It is equitable if it allows market access for smallholders with an equitable balance of risk, responsibilities, and benefits, whereas it is effective when it strengthens the purchaser's access to consistent supplies at a reasonable price (Sopov et al., 2014). From the perspective of gender awareness, this business is affordable if it allows them access to markets to sell food which the poor can afford; their prices are not only for profit making, but other social and environmental benefits can allow their business to sustain over time. However, this is only possible if gender barriers do not exist, thus allowing women to make decisions by themselves (i.e., increasing their capabilities).

Fourth, a business is efficient or commercially viable or profitable if it improves its financial sustainability (Sopov et al., 2014) making profits durable. Thus, from the perspective of gender awareness, a business is viable if no or few gender barriers exist and if it generates sustainable profits, including financial returns and non-monetary benefits.

Fifth, a business is adaptable if it enables flexible responses to changing market, social, and environmental conditions (Sopov et al., 2014). From the perspective of gender awareness, a business is adaptable if its actors (e.g., women with poor resources) can cope with their business environment, including market conditions, institutions, social/cultural norms, and the natural environment (climate risk). Hence, the integration of gender awareness and inclusiveness in business is a good way to increase successful women's capabilities.

Capabilities and functioning

Capability approach

Addressing gender inequality and women's exclusion through empowerment in value chains is feasible if it is possible to enhance their capabilities (Riisgaard et al., 2010). Extensive literature has been built on Sen's work on the capability approach in terms of contestations. Although this literature recognizes the relevance and holistic basis of the capability approach as a strength, it also highlights its weakness relative to its operationalisation. Indeed, the first body of literature considers the capability approach a normative framework for the evaluation of individual wellbeing and social arrangements (Sen, 1985; Bebbington, 1999; Nussbaum, 2000; Alkire, 2002; Clark, 2002; Frediani, 2010). Another body of literature considers the capability approach an informational space for making evaluative judgements (Sen, 1997; Deneulin and Stewart, 2002; Frediani, 2010). Both perspectives defend the idea that human wellbeing is multidimensional, including income and perceptions. By contrast, a third body of literature focuses on concerns related to the operationalisation of the capability approach and its openness and incompleteness in assessing capabilities (Comin, 2001; Biggeri et al., 2006; Alkire, 2007; Crocker, 2007; Comim et al., 2008; Frediani, 2010). The main idea is that the complexity of the capability approach allows for various interpretations and operationalisations of the capability concept. Based on this contested debate, what does the capability approach encompass in practice? Sub-section "Capability analysis framework: functioning, capabilities and agency" gives an answer to this question.

Capability analysis framework: Functioning, capabilities and agency

The capability approach, as developed by Amartya Sen, focuses on the moral significance of an individual's capability (ability) to achieve the kind of life they have reason to value and to enhance the substantive choices they have (Sen, 1999; Wells, 2012). As such, the approach puts human beings at the center and manages to assess their actual abilities that they achieve and acquire (Wells, 2012). This definition involves three main concepts which constitute the core elements of the capability approach: functioning (also achievement), abilities or capabilities, and agency and the way they are interlinked. First, functioning consists of the states of "being and doing" (Wells, 2012, Core concepts and Structure of Sen's Capability Section, para.2), that is, the states and actions forming individual's being (Sen, 1992).

Second, capabilities refer to the "set of valuable functioning that a person has effective access to" (Sen, 1992; Wells, 2012, Core concepts and Structure of Sen's Capability Section, para.2). Thus, "a person's capability represents his or her effective freedom to choose between different functioning combinations," that is, a choice "between different kinds of life that she or he has reason to value" (Gore, 1997; Wells, 2012, Core concepts and Structure of Sen's Capability Section, para.2). As such, capabilities are a mixture of achievable functioning for a person and therefore constitute her opportunity set (Gore, 1997). Regarding the concept of freedom, the literature distinguishes wellbeing freedom from agency freedom (1992). The former refers to what an individual considers important for her wellbeing, whereas agency freedom pertains to one's freedom to select and make what she or he values the most (Sen, 1992;

Frediani, 2010). This distinction is interesting as it sees freedom as both an instrument to reach development and an outcome of development (Sen, 1992).

Third, regarding agency, an agent acts and generates a change (Sen, 2001). A person's achieved change merely depends on his or her personal values and goals. Agency refers to a person's capability to engage in the economic, social, and political activities of society (Alkire, 2005).

In this study, the capability approach attempts to understand WSEs at two levels: as an individual agent and a collective agent (Narayan, 2005). First, an individual agent is related to the WSEs individually considered as agents. From this perspective, the capability analysis framework is applied to each WSE to understand her capabilities and functioning in the context of her living area, vulnerability, and her cultural, environmental, political, and social positions that affect her agency. This implies looking at the resources she has access to and which can be converted into valuable functions based on her ability to do so. For example, the ability of a WSE to convert the resource that she has access to valuable functioning depends on her personal physiology, social norms, or cultural and physical environment (Wells, 2012). In this vein, individual capabilities, functioning, and agency can be distinguished. In other words, WSEs have individual access to resources, individual opportunities, and individual abilities to make valuable choices related to (i) their individual goals and values, (ii) individual freedoms and individual capacities to convert resources into their individual functioning, and (iii) individual cross-cultural norms, social positions, political power relations, and so on.

Second, the collective agent refers to each WSEs' group as an organization of human beings, since inclusive business intervention in the value chain usually targets organized women in the group (Ros-Tonen et al., 2019). WSEs' groups are organizations comprised of members who are part of society. The structure and dynamics of such organizations are deeply embedded in the behavior of the individuals that compose them. For this level of analysis, and by analogy to the individual level, this study refers to the concepts of collective capabilities, collective functioning, and collective agency. In other words, WSEs' groups have collective access to resources, collective opportunities and choices, collective abilities, collective goals and values, collective freedoms, collective agency to convert their collective resources into collective functioning, and so on. The group mentioned herein is another entity or organization whose dynamics involve another type of consideration.

The theory of organizations in economics, management science, and sociology can help explain the motivations and purposes of creating an organization and its functioning (Hatch and Cunliff, 2006; Bressy and Konkuyt, 2008; Natemeyer and Hersey, 2011; Aïm, 2013). A relevant reference that structures the analysis is the principal-agent problem theory. In this theory, the concept of agency is different from that in the capability approach: an agent is a person acting on someone else's behalf (Sen, 2001). In other words, agency in the theory of organizations is linked to the concept of information asymmetry, which claims that economic agents do not have access to the same level of information (Akerlof, 1970; Hatch and Cunliff, 2006; Natemeyer and Hersey, 2011). Consequently, WSE groups can be analyzed within this framework of organization theory.

Therefore, this study does not reject the concept of an agent presented by Sen (2001). Instead, it considers Sen's definition of an agent as complementary to the definition of agency from the theory of organizations. Therefore, beyond the fact that an agent is a member of society, his or her behavior as an economic agent within an organization can also reveal additional information about his or her access to resources and his or her abilities to transform them into valuable functioning.

In so doing, the current study came across a holistic-specific understanding of WSEs' capabilities, which is analogous to the concept of glocalisation in international marketing (Sarroub, 2009; Hollensen, 2014). The holistic side (global) considers the capability approach to identify all the factors influencing the access of human beings (agents) to resources and their capacities to convert them into valuable functioning. The specific side (local) of the analyses focuses on a human being as an economic agent, that is, influenced by both his or her agency as a member of society and his or her economic agency in the economic arena, hereof called the value chain. It appears that both types of agencies are two sides of the same coin as they express two different but interlinked realities (Wells, 2012).

Overall, this rich literature shows that the capability approach is often applied to human beings. However, this approach is too broad for use in specific cases of WSEs. The capability approach considers all societal and environmental factors of life within the community, such as values, culture, and norms (Sen, 1985, 2001). As such, the capability approach contributes to understanding the interactions between WSEs and their living environment (household and community) and how this affects their daily profit-making activities. However, the capability approach does not fully capture the behavior of women as individual economic agents within their (business) associations/groups. To bridge this gap, firm-level economic wellbeing provides a sound analytical framework.

Firm level economic wellbeing: Firms, businesses and entrepreneurs

A firm-level economic wellbeing refers to "the business command over resources, relations, performances, goals and satisfaction thereof' (Pouw, 2017, p. 95). Three main concepts are involved: firms, businesses, and entrepreneurs (Pouw,

2017). A firm is defined as "an organization engaged in the paid production of goods and services to customers for profit and other gains. In addition, a firm has a legal component, whereas a business refers to any profit-making activity" (Pouw, 2017, p. 97). In contrast, "an entrepreneur is a person who organizes, manages and assumes the risks and rewards for a business venture, including non-monetary business risks and rewards" (Pouw, 2017, p. 97).

From this perspective, firms, businesses, and entrepreneurs (FBEs) usually operate with the motivation to make profits and/or social and/or environmental gains. Specifically, they are key resource agents that produce paid goods and services, create employment, and form part of an entrepreneurial environment in which individual women and men can find jobs (Pouw, 2017). Societal norms and behavioral rules and practices, including those related to gender, influence women's and men's activities, access to resources, and generated outcomes in FBEs (Pouw, 2017). The outcomes of FBEs activities contribute to firm-level economic wellbeing, which is partly influenced by the entrepreneurial or stakeholders' subjective evaluations of aspired goals and satisfaction or dissatisfaction.

This theoretical thinking on firms, businesses, and entrepreneurship suggests having a particular look at the concept of profit-making; profit-making guides the definition of business in value chain analysis. Indeed, the position of Pouw (2017) on business nature within the framework of firm-level economic wellbeing is questionable because it implicitly acknowledges the existence of competition among value chain stakeholders. As in industrial economic theory, profit-making businesses lead to competition among market actors (Encaoua, 1986; Jaworski et al., 2000; Carlton and Perloff, 2005). The main idea is that perfect competition leads to efficiency and innovation of firms, with more affordable goods and services exchanged in the market, and generates profits for successful firms (Encaoua, 1986; Carlton and Perloff, 2005; Brooke, 2010). This perspective is contestable regarding WSEs' survival characteristics (Zoumba, 2018; Likoko et al., 2019), which does not fit the conventional entrepreneurial model (see Gender awareness in business). While conventional firms require initial capital (apart from their workforce) to start their activities, they usually lack such capital (Vossenberg, 2016; Pouw, 2017). As they lack access to credit, the financial risk undertaken differs from that undertaken by a conventional firm. Therefore, the concept of profit needs to be differentiated as normal vs. supernormal profit. Supernormal profit refers to profit above normal profit, defined as the minimum return necessary to keep a firm in business; this particularly happens in a market with a monopoly (Encaoua, 1986; Carlton and Perloff, 2005). Normal profit enables a firm to pay a reasonable salary to its workers, managers, and shareholders, as is the case in a market with perfect competition (Encaoua, 1986; Jehle and Reny, 2000; Bianchi and Henrekson, 2005; Carlton and Perloff, 2005; Hawley, 2009; Brooke, 2010).

Supernormal profit (typically for monopolies) is seen as an extra profit or "abnormal profit" because it is above the necessary profit, thus it creates incentives for other firms to enter the value chain or business sector if they can (Carlton and Perloff, 2005; Brooke, 2010). Therefore, it generates competition between firms that supply goods and services. As the poorest engaged in survival, entrepreneurial activities are usually vulnerable to business competition, raising concerns about their ability to seek supernormal or normal profits. Indeed, the poorest are the most vulnerable to uncertainty or risk, which determines the expectations to earn profit (Knight, 2006; Brooke, 2010), but they lack the means to bear such uncertainty or risk. Thus, they expect revenues earned from their activities to be able to cover the costs of inputs used in their business and their households' basic needs (food, education, health care). Hence, in this study, profit-making activities refer to earning at least an income or profit (after deducting their direct costs), which can be negative, as stated by Knight (2006).

Hence, the firm-level economic wellbeing perspective is an important framework enabling the identification of agents involved in a value chain and how they organize, manage, and assume the risks and rewards for any profit-making activity. The framework also helps to identify the businesses or profit-making activities encountered in value chains, and to what extent they are gender-aware and inclusive. However, the FBE cannot provide clear information on the social institutions that women face in their households and communities and how they behave in such conditions. Furthermore, this theoretical model does not explain how the economic environment of women in business (their business group) affects their social lives (within their household and community). This knowledge gap can be filled using the capability approach, particularly the holistic-specific approach. In particular, the firm-level economic wellbeing approach helps identify resources, roles, activities, and outcomes (Pouw, 2017). Resources can be referred to as assets to which WSEs have access to (Bebbington, 1999; Frediani, 2010). Specifically, resources encompass time, natural, spatial, human, and financial resources (Pouw, 2017). Activities are referred to as business activities, including food production, processing, and marketing (WFEs Project, 2015). The outcome, which is the result of the process of transforming resources, is the economic wellbeing of WSEs (Pouw, 2017). This encompasses material gains (profit earned) and non-material gains such as good customer relations, solid business reputation, brand name, and so on Pouw (2017). From a broad perspective, the outcome of this process can be referred to as the achievement of women's empowerment (Sen, 1992).

Theoretical perspective and discussion

From the literature presented above, this paper suggests a different conceptualization of a value chain aimed at addressing gender inequality and the inclusion of BoP people, particularly women survival entrepreneurs. By naming it "gender-aware inclusive value chains (GAIVC), this perspective of value chains brings in the Foucauldian perspective on humans to the conceptualization of a value chain. Indeed, a value chain should be analogous to the human body, as it is the best way to address the issue of gender inequalities and inclusion of BoP populations in the food system, particularly WSEs at the community or local level.

Hence, three main concepts and their interactions characterize a gender-aware inclusive value chain (GAIVC): (1) WSEs' capabilities, functioning, and agency; (2) gender-aware inclusive business (GAIB); and (3) the other components. They form the theoretical perspective proposed by this paper.

Theoretical perspective

WSEs as societal and economic entities

The capability approach and firm-level economic wellbeing are individually limited to clearly explaining WSEs behaviors (and their groups) both as individual members of society/communities/households and economic agents within their business groups (see Gender awareness in business and Firm level economic wellbeing: firms, businesses and entrepreneurs). Thus, this study combines the capability approach with the firm-level economic wellbeing framework (i.e., the resources, roles, and activities in a business). This helps obtain information on agents (individual women) as members of society and how this influences their daily entrepreneurial activities. Second, the paper assesses how an "economic" agent makes the connection between his or her agency (behavior) as a member of society and as an entrepreneur. This allowed us to capture how WSEs behave as agents within their groups and how this influences their gains from their activities. Interestingly, combining both approaches helps to better understand how institutions, including groups' governance, affect the dynamics of GAIVC.

Three main elements were involved: (a) WSEs as societal and economic agents, (b) capabilities, and (c) functioning. First, in the local food system (e.g., in urban areas), WSEs usually produce and sell or produce and/or buy their products at the production site or marketplace. The self-consumption of their production exists, but is marginal because their prime objective is to sell their products and obtain revenue. In this framework, WSEs are expected to drive the business model and are among the key stakeholders/agents (nervous system) of GAIVC. A better understanding of these agents requires a thorough examination of their socio-demographic characteristics (e.g., age, education, marital status, ethnic group, living place, access to food). Thus, in this paper, WSEs or their "agency" will be better described through these individual and collective socio-demographic characteristics.

Second, as "capabilities" is a concept difficult to operationalise, and it only focuses on WSEs as societal agents, this paper bridges the disconnection with the firm level approach. Thus, "capabilities" are the sets of valuable functioning, or the sets of resources (i.e., assets that include time, natural, space, human, relational and financial resources) at WSEs' disposal (See section "Capabilities and functioning"). In addition, a distinction is made between individual and collective resources for WSEs individually and WSEs groups. Moreover, the study considered all changes in these resources due to the WSE's business model as "capabilities."

Third, "functioning" refers to achieved empowerment or functioning according to the capability approach. This study adopts the definition of firm-level economic wellbeing by stating that "functioning" refers to the most valued changes in WSEs' living conditions brought about by the changes in their capabilities (i.e., time, natural, space, human, relational, and financial resources) due to business. They are material and non-material, and include quality food, relations, reputations, control of resources, and decision making. Collective valued resources and individual valued resources also exist for individuals and groups, respectively.

Hence, WSEs' agency and capabilities are key elements that affect their business strategies, and vice versa. By adopting the definition of strategy as a set of plans or decisions made to help organizations achieve their objectives (Mainardes et al., 2014), this study considers that WSEs' characteristics significantly determine these dynamic strategies and vice versa. These strategies respond to the dynamics of the internal and external environments in which WSEs evolve. Thus, the first hypothesis (H1) that "WSEs' individual and collective characteristics or agency, capabilities, and strategies primarily shape their business model" can be formulated and field-tested.

Gender-aware inclusive business: Dimensions, indicators and relationships

Gender-aware inclusive businesses alleviate both gender inequality and women's exclusion from formal economic systems (see section "Inclusive business"). It encompasses food production, processing, and vending activities, whereby each activity is considered innovative, adaptable, applicable, affordable, and viable. It has five dimensions with several indicators or variables (see Table 1). This table provides questions that helps draw up the indicators of such a business model for field testing and implementation. Table 2 presents the operational indicators of gender-aware inclusive businesses.

TABLE 1 Conceptualizing a gender-aware inclusive business (GAIB).

Components	Questions involved with respect to WFE's
Innovative (I)	Does a (specific) market or place that creates successful business exist?
	Does the business induce opportunities?
	Are the tools used in the business built upon customary wisdom and environmental sustainability?
	Are the tools used in the business practices (techniques) built upon customary wisdom and environmental sustainability?
	Are there any social/cultural barriers? Any ecological barriers? Any geographic barriers? Any economic barriers?
Credible (C)	How is the level of coordination or organization between producers?
	How is the relationship with retailers? Relationship with end-consumers? Relationship with restaurants/processors?
	What is the duration of the WSEs/WFEs' group?
	How is the group's governance dynamics?
	How is the dynamics of their relationship with retailers? How is the dynamics of their relationship with end-consumers? How is the dynamics of their relationship with restaurants/processors?
	To what extent (rate) are buyers attached to the business (site/place)?
	To what extent do gender barriers matter in the commercial relations (vertical)?
Affordable (A)	What is the proportion of low-income buyers (under the poverty line in Burkina Faso) who have access to these business products?
	How do buyers perceive the affordability of products?
	Are all actors in the value chain exposed to the risk (climate extreme, institutional)?
	What are the transportation costs for resellers (from farm to marketplace)?
	What are the transportation costs for end-consumers (from home to farm)?
	What is the responsibility of actors in the chain; is the business market-driven or producer-driven?
	What actors in the value chain do you perceive to be the most rewarded?
	Are there any gender barriers for buyers' access to affordable food prices?
Adaptable (A)	What is WSEs/WFEs' ability to cope with their business environment (i.e., competing with other value chains)? Is there any competition between WSEs/WFEs evolving in the same value chain?
	To what extent are WSEs/WFEs able to cope with buyers' requirements on food availability? Food diversification? And food quality?
	What is the degree of exposure and ability of WSEs/WFEs to cope with political change (land politics, urbanization politics)?
	How do you perceived WSEs/WFEs' ability to cope with the economic institutions and resources such as: access to credit? Access to water? Access to inputs/fertilizers? Access to information? Access to training/knowledge?
	How is the social environment of WSEs/WFEs? Are they able to cope with their norms over time?
	To what extent do gender barriers constrain WSEs/WFEs' in their business?
	To what extent are WSEs/WFEs able to cope with climate extremes such as flooding and drought?
Viable (V)	What is the frequency of buyers on the production sites per month?
	What is the value of the purchased food per buyer and month?
	What is the level of production cost per woman and per year?
	What is the level of revenue gained per woman and per year?
	What is the level of benefit (difference revenue and production cost) per woman and per year?
	What are the producers' perceived benefits/outcomes of their business?

Source: The Author.

From this table, the components and indicators of gender-aware inclusive business are drawn.

How does a gender-aware inclusive business approach bring about changes in WSEs' various resources and agencies (see WSEs as societal and economic entities)? To answer this question, a second (field-testable) hypothesis (H2) is: "an innovative, credible, affordable, adaptable, and viable business is materialized by a significant increase in WSEs' individual resources as well as positive change in their agency/behavior."

"Other components"

The "other components" of the gender-aware inclusive value chain comprise the structures, non-WSE actors, environment, and institutions. The "structures" refer to the physical and nonphysical elements. Physical elements include infrastructure, such as buildings, roads, equipment, and warehouses. Non-physical elements comprise (a) vertical linkages or vertical integration, that is, how actors at different nodes of the value chain are organized (e.g., are producers and vendors of their products in the marketplace?) (b) The horizontal linkages or

TABLE 2 Gender-aware inclusive business components, indicators.

Components	Indicators
Innovative (I)	Existence of local scale market or place
	Creation of opportunities
	Sustainable value creation
	Zero gender barriers
Credible (C)	Stable commercial connection at horizontal level
	Stable commercial connection at vertical level
	Long term commercial connection at horizontal level
	Long term commercial connection at vertical level
	Buyer's attachment to the business (site)
	Zero gender barrier in their commercial relations
Affordable (A)	Access to market where poor people (purchasers) can access too
	Reasonability of the prices
	Equitable access of smallholders to the local market
	Zero gender barriers at the chains' nodes level
Adaptable (A)	Business environment
	Market conditions requirements
	Political institutions requirements
	Economic institutions and resources
	Social environment
	Ability to cope with natural environment
	Zero gender barriers in the environment
Viable (V)	Demand
	Production cost
	Revenue
	Benefit
	Other outcomes[1]

[1]Including positive change in gender relationship between men and women.

coordination, that is, how actors at the same node of the value chain are organized (e.g., are food producers organized into groups or not?). Thus, a third (field-testable) hypothesis (H3) is that "infrastructure, level of vertical integration and level of horizontal coordination in a value chain shape the capabilities, agency and strategies of WSEs.

"Non-WSE actors" refer to the other people (food consumers or purchasers and other stakeholders such as service providers – NGOs, public services, financial services – intervening in the value chain) and how they communicate together with WSEs. Communication refers to how information and knowledge flow among and between stakeholders at the same node and across nodes. For example, how do public service providers reach WSEs when a new technology is available for adoption, or how consumers are informed of the availability of food products from gardens?

"Environment" refers to natural environment (e.g., climate change risk, droughts and floods) and competitive environment (other value chains surrounding the ones which involve WSEs environment). For example, how do conventional food value chains influence organic food value chains in urban food systems?

"Institutions" refers to all formal and informal political, economic and gender norms and rules in the business field (see Gender awareness in business). "Political institutions" refer to formal and informal rules (laws, policies, political corruption) adopted at the state level to regulate social and political life. The idea is to understand how policies and governance systems contribute to forging WSEs' capabilities, agencies, and strategies, as well as the business model involved.

"Economic institutions" refer to formal and informal market rules (including corruption) that shape the business environment. The idea is to understand how these rules contribute to forging WSEs' capabilities, agencies, and strategies, as well as their business model.

"Gender" refers to the formal and informal norms on how women and men's roles are perceived and how these cultural power-relations are displayed in the business. For example, how do women culturally perceive themselves vis-à-vis men, what is the power balance relationship between them, and what future do they perceive in terms of gender equality? Gender policies addressing gender inequality and empowerment of powerless people can also shed light on gender issues. Analyses of how institutions influence WSEs' capabilities, agency, and strategies, as well as their business model, are contextual.

Hence, the field-testable hypothesis is that the other components individually shape WSEs' business strategies, capabilities, and functioning. Figure 2 below shows the conceptual model on gender-aware inclusive value chains.

Discussion

This result on value chain concept can be compared to the "inclusive value chain collaboration" recently proposed by Ros-Tonen et al. (2019). The latter sound analytical framework has two main commonalities with the what is proposed in this paper. First, both studies address gender issues and BoP populations' (smallholders notably) in an integrated manner in value chain conceptualization. In doing so, both studies consider human right and dignity (Ioannou and Serafeim, 2012) in the analysis and collaboration in a value chain. Second, both studies consider "inclusive value chains" as a framework where inclusive business models are conducted (Ros-Tonen et al., 2019, p. 13; Kini, 2022).

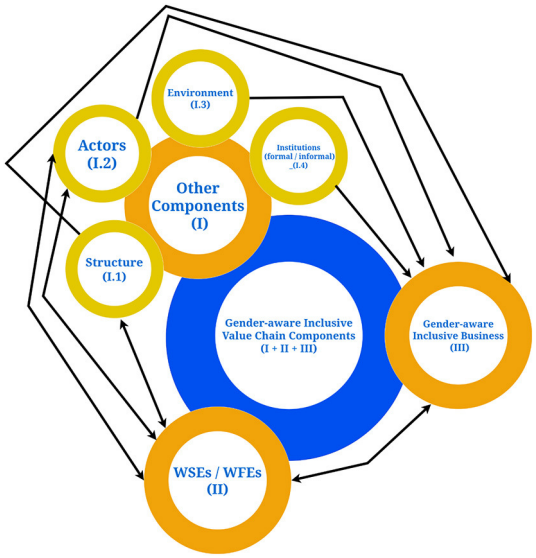

FIGURE 2
The conceptual framework of Gender-aware Inclusive Value Chain.

However, the current paper contrasts with Ros-Tonen et al. (2019) on the following points. First, the authors' theoretical model merely pertains to existing global value chains (and how to integrate the BoP population as well as address gender barriers in such value chains); whereas, the model proposed in the current paper is more directed toward new value chains. Second, they focus on long value chains (international or cross-country); whereas GAIVC focuses on short value chains perspective. While relevant, the authors position of value chain is the one which has been criticized by Likoko and Kini (2017). The latter assume that this way of integrating the BoP populations in business is merely the position defended by SNV and WBCSD (2011) or multinationals, which integrated these populations as consumers, suppliers/distributors or producers of certain raw materials (Likoko and Kini, 2017). In such a way, the BoP population cannot be drivers of the business, meaning that they have little power or influence on the value chain dynamics. This is recognized by Ros-Tonen et al. (2019, p. 14) themselves when they state that in such value chains, there is a great potential of adverse incorporation and exclusion, thus they are not inclusive of all the farmers. Third, their model cannot fully address the problem of power relations as BoP populations are powerless in such business value chains and are forced to adopt decisions made by the drivers of the business (mostly the multinationals) (Kini, 2022). In contrast, the approach to value chain proposed in the paper is meant to address the unequal power relations. Indeed, if each stakeholder sees herself or himself as complementary instead of a competitor, the power relationship (gender-based or poverty-based) has a great chance to be balanced among and between themselves (Kini, 2022).

Conclusion

This paper has provided a sound bottom-up approach addressing both gender issues and BoP inclusion in business and value chains. Indeed, gender-aware inclusive value chains presented in this paper provide sufficient knowledge addressing gender inequalities faced by resource-poor women. In addition, empirically testable hypotheses described in this paper show how business models for inclusiveness in food value chains affect the capabilities and functioning of women survival entrepreneurs (WSEs).

Hence, this paper has contributed to the literature by bringing the Foucauldian perspective on humans to the conceptualization of a value chain. From the conceptualization of the gender-aware inclusive value chain, this paper has identified the existing (actors, structures, environment and institutions), communicative (knowledge and information flow) and productive (production outputs) components of the value chains. It also shows the interactions existing between elements of each component and how they contribute to the overall performance of the value chain.

The proposed framework is designed for policy makers, NGO (as development practitioners), and businesses, particularly in low-income countries where poverty and gender inequalities hinder their development. Indeed, it may serve as a tool to truly implement, assess, and monitor business models, "so called" inclusive of the poorest, particularly the poor resources women based on the proposed indicators.

To Kini (2022) "the main challenges will be significant when scaling-up this model to a larger dimension, exposing it to rural-urban interactions at local, meso and national levels. The current research did not investigate this, and future research should fill this gap in knowledge. Indeed, political and economic institutions will be at the heart of such upscaling, and a deep understanding of these political and economic institutions will help to assess the accuracy of the business models proposed as a result of the current research. As the dominant business model supports vertical and horizontal integration in the value chains in the food sector, the most powerful actors in the sector could become real threats for the actors participating in the gender-aware inclusive businesses and value chains, as they might see their market shares reduced. Therefore, improving the understanding of the power of economic and political institutions to support the implementation of poor-driven business models will be insightful for further decision making" (p. 207).

Moreover, "to scale-up this business model and the value chain from a small scale (within urban or local areas) to the national scale, the process should target the urban

areas to replicate the business model. At a small scale, and in each city of a country, this model can produce very interesting outcomes in terms of income, food supply (diversity), food quality, relationships to the benefit of the whole urban communities. In other words, at a small scale, such a model could cope with the competition of the other value chains. Thus, this small-scale business model might be gradually extended to cover much more of a country" (Kini, 2022, p. 207).

However, the proposed theoretical model does not explicitly highlight an important performance indicator related to the percentage or weight with respect to the entire value chain. Indeed, given that some hypotheses of the model are related to individual characteristics, collective characteristics, infrastructure, or sustainable enterprise, it appears appropriate to correlate the number of participants in association with the number of associations in each city according to the number of inhabitants. In other words, larger cities may require a greater number of members per group, thus strengthening the value chain. Therefore, this paper recommends future applications should consider these performance indicators when testing the hypotheses introduced in the theoretical model.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

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Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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EDITED BY
Silke Maria Stöber,
Humboldt-Universität zu Berlin, Germany

REVIEWED BY
Ghassan Baliki,
ISDC - International Security and Development Center gGmbH, Germany
Tilman Brück,
Leibniz Institute of Vegetable and Ornamental Crops, Germany

*CORRESPONDENCE
Hendrik Hänke
✉ hendrik.haenke@welthungerhilfe.de

†These authors share first authorship

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Food systems transformation in fragile contexts, a practitioner's perspective

Hendrik Hänke*†, Arno Bratz†, Stefanie Griebel, Jasmin Koottummel and Hugo Verkuijl

Sector Strategy, Knowledge and Learning Unit, Welthungerhilfe (WHH), Bonn, Germany

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1. Introduction

After two decades of progress, food and nutrition security (FNS) has started to deteriorate again (von Grebmer et al., 2022). In 2021, 828 million people were undernourished, and around three billion people could not afford a healthy diet (FAO et al., 2022). The vicious combination of increasing conflict, climate variability and extremes, economic effects of Covid-19, and global food price hikes amidst Russia's war in Ukraine, creates a grim outlook for FNS worldwide (FAO et al., 2022; WFP and FAO, 2022), and particularly for people in fragile contexts (von Grebmer et al., 2022).

A transformation of the global food system (the entire range of actors and their interlinked value-adding activities involved in food production along with the broader economic, societal and physical environments in which these activities are embedded (FAO, 2018) is needed to achieve zero hunger and improve nutrition while managing trade-offs with biodiversity, climate change, and Sustainable Development Goals (Willett and Rockström, 2019; Rockström et al., 2020).

Contexts are classified as fragile through a combination of exposure to risks and shocks and insufficient coping capacities to manage, absorb, and mitigate those risks, e.g., by a state or system (OECD, 2022). Fragility can also be identified on a village or individual level (Baliki et al., 2022). There is a growing consensus that food systems transformation [i.e., toward sustainable and resilient food systems that generate food security and healthy diets for all (WHH, 2022)], must address the challenges of populations in fragile contexts as a principal objective (Queiroz et al., 2021). The reasons for this are three-fold. Firstly, the recent failures of food systems are most harshly felt by people in fragile contexts, as they are more prone to facing conflict and climate shocks, volatile government structures, and unsustainable coping capacities (FAO et al., 2022; WFP and FAO, 2022). Out of 44 countries that face serious or alarming levels of hunger according to the Global Hunger Index, 40 are classified as fragile (OECD, 2022; von Grebmer et al., 2022; see Supplementary Figure 1). Secondly, many of the biosphere's important carbon stocks and biodiversity hotspots are located in fragile settings (Barrett et al., 2011; Karsenty and Ongolo, 2012; Seto et al., 2012). Fragile settings in South America, Sub-Sahara Africa, and South-East Asia account for approximately 34.9%, of total carbon stock from above and below-ground biomass in these regions (Saatchi et al., 2011; OECD, 2022). Thirdly, biodiversity hotspots in fragile contexts are at an elevated risk of being diminished further as a result of food insecurity coping mechanisms. Out of ten countries and seven biodiversity hotspots identified as biodiversity-food security conflict hotspots (Zhao et al., 2022), nine countries and four biodiversity hotspots are located in fragile settings (OECD, 2022; see Supplementary Figure 2). To improve the sustainability and climate resilience of food systems, transformation processes must integrate FNS, biodiversity and climate, and anti-fragility objectives.

Food systems transformation in fragile contexts remains insufficiently considered in development, academic and political discourses. With a few notable exceptions (see Pingali et al., 2005; Townsend et al., 2021; Baliki et al., 2022; von Grebmer et al., 2022) the available literature on food systems transformation treats fragility as either a negative effect of unsustainable intensification (e.g., Rockström et al., 2020), or ignores it entirely. However, there is also evidence that food systems are affected by the climate crisis, which in turn trigger conflicts (Läderach et al., 2021). Politically, a consensus arose from the United Nations Food Systems Summit in 2021 that FNS should be linked to concepts of resilience in protracted crises, and that the Humanitarian-Development-Peace Nexus should be prioritized in fragile contexts. However, no fragility-related commitments were reached, and no tangible solutions were developed to address and reduce fragility as part of food systems transformation. A much stronger policy focus on the challenges of people living in fragile contexts is needed if food systems transformation is to be successful (Baliki et al., 2022).

This opinion paper calls for a much stronger focus of food systems transformation agendas on fragility. It includes our views on how to contribute to immediate FNS and long-term sustainability and resilience goals from a practitioner's perspective. We illustrate this through country examples of (i.) interventions and approaches that we know work well, as well as (ii.) those that are less backed up by evidence yet and therefore require more research.

2. Food systems challenges in fragile contexts

One of the most widely used methodologies for assessing fragility is the Multidimensional Fragility Framework (MFF; OECD, 2022). MFF assesses fragility mostly at a national state level and is based on 57 indicators across seven dimensions of fragility: economic, environmental, human, political, security, society, and health. Yet, other scholars have also conceptualized fragility through human security, economic inclusion, and social cohesion at the micro (village and individual) level (Baliki et al., 2022).

A trend toward increased fragility can be observed throughout all dimensions over recent years (OECD, 2022). Food systems in fragile contexts frequently face various challenges related to their risk exposure profiles and coping capacities. Common risk exposure-related challenges include disasters, conflict, and food supply disruptions (Guha-Sapir et al., 2022; OECD, 2022). In addition to destroying agricultural produce, assets, and infrastructure, disasters can cause involuntary migration, labor shortages, and the abandonment of agricultural areas, thus hampering the availability and accessibility of food. Conflict also poses a major challenge to food systems in fragile contexts as it is increasingly caused by, and contributing to, climate extremes, environmental degradation, and natural resource shortages (Läderach et al., 2021). Conflict also reduces household resilience to food security shocks (Brück et al., 2019). Lastly, as most fragile contexts rely on food imports, people living in them are more vulnerable to non-accessibility due to global supply chain disruptions and price hikes (OECD, 2022), which have substantially increased in the past years.

Coping capacity-related food systems challenges in fragile settings are manifold and context-specific. Communities and households in fragile settings are also often forced to rely on unsustainable coping strategies, such as the sale of productive assets or deforestation, thus jeopardizing their long-term resilience, and climate and biodiversity objectives (SEADS, 2022). Low institutional capacity may hamper the ability of national, regional, and local governments to secure the human right to food (OECD, 2022).

3. Emerging practices for food systems transformation in fragile contexts

While the need to consider fragility in food systems transformation is evident, the question of how to do so has not yet been much explored. Based on our experience, we suggest a two-pronged approach. Firstly, the immediate FNS needs of acutely food-insecure populations must be addressed in a way that prevents a local system collapse. Secondly, these immediate interventions need to be complemented with structural and systemic change processes that facilitate the achievement of sustainability, resilience, and anti-fragility goals in a way that contributes to improved FNS.

This section is structured in two subsections. First, we provide examples of system-sensitive interventions that have been proven to work well in fragile settings. Second, we illustrate how to complement these with a two-pronged approach drawing on our work in Mali, which requires more research to yield robust evidence and recommendations.

In fragile contexts, where decentralized food supply chains play a crucial role in achieving healthy diets, vegetable gardens are exceptionally important. Home gardens in refugee camps, schools or communities contribute to FNS, livelihood diversification, and diversified vegetable consumption at home and in schools (Millican et al., 2019; Schreinemachers et al., 2020). Furthermore, short-cycle crops bring intermediate benefits (SEADS, 2022) that ideally are multi-purpose in use, nutritious, give good yields under low input conditions and influence of a-/biotic stressors.

Another tool to bridge the gap between immediate humanitarian needs and local food system support are cash and voucher assistance (CVA) programs. Cash transfers can be at low costs, are fast and easy to handle, increase purchasing power of recipients, allow flexible expenses, and support local markets (Peppiatt et al., 2001; Gentilini, 2016). Evidence from fragile contexts such as Ethiopia, Iraq and Syria shows that cash transfers and agricultural asset transfer can improve food security, dietary diversity, and a range of other outcomes (Phadera et al., 2020; UNICEF et al., 2020; Weiffen et al., 2022). Still, some evidence from Congo suggests that cash transfers did not improve FNS (Aker, 2017).

In Mali, more than 50% of the population lives in extreme poverty, and it ranks 15 in the list of most fragile countries. Recently, staple food prices and food insecurity increased dramatically (de Roo et al., 2020). Moreover, conflict and climate extremes directly reduce the ability of agro-pastoralists to exercise livelihood activities (Läderach et al., 2021). The increasingly

variable seasonal weather cycles push traditional herders and farmers of different ethnic groups toward the edge of their communal resilience and result in increased conflict and internal displacement (OECD SWAC, 2020). Here, WHH implements a two-pronged approach where social protection that responds to immediate humanitarian needs is coupled with longer-term food system transformation in a way that addresses the Humanitarian-Development-Peace Nexus and fragility. Social protection through CVA is provided to the most vulnerable people. These temporary interventions are accompanied by economic recovery measures that support vulnerable population to regain their livelihoods e.g., restoration of agro-pastoral assets and provision of farming and vegetable gardening to boost own food production. Moreover, we facilitate multi-stakeholder dialogues to build trust, strengthen social cohesion, and to find structural solutions to reduce pressure on natural resources such as collective usage agreements, improvements of water availability for agriculture and livestock, and the construction of natural pathways that protect agricultural fields during livestock movements.

Such food system interventions and their effects on peace and fragility outcomes are still insufficiently explored through empirical studies and monitoring and evaluation methods but require careful consideration as they are increasingly applied. Other countries where we currently use the two-pronged approach include e.g., Lebanon, Iraq, Syria, Yemen, South-Sudan, Democratic Republic of Congo, Pakistan, Madagascar and Haiti.

4. Conclusion and policy recommendations

Localized efforts to address the challenges of people in fragile contexts must be complemented by larger-scale food systems transformation processes. Governments, funders, practitioners, and academics should address food systems challenges in fragile contexts as a primary policy objective and focus on the areas and dimensions that are most fragile (cf. Baliki et al., 2022).

To do that, multi-stakeholder approaches are needed and require careful facilitation and research. Our experience has taught us that while the specific solutions to advance food systems transformation in fragile contexts are highly context-specific, a two-pronged approach should be followed. The immediate FNS challenges must be addressed in a way that prevents a local system collapse, and these interventions must be accompanied by systemic transformation processes that reduce fragility to contribute to improved sustainability, resilience, and FNS. Our policy recommendations include:

1. Research organizations, humanitarian and development organizations, and affected food system actors should work together to develop, implement and evaluate Theories of Change for food systems transformation in fragile settings. The focus should be on understanding better how food systems are shaped by fragility and vice versa, and which combination of key levers alongside the two-pronged approach seem the most promising to deliver FNS in a sustainable and resilient fashion in fragile settings. The transdisciplinary development of theories of change could serve as an anchor for the development of more context-specific evidence syntheses and gap maps.
2. The request for more research and evidence on which interventions matter and work in the short, medium and long-term, requires not only that more but also that the "right" funding is available. Currently, too few funding opportunities promote integrated research and implementation projects that allow for more experimentation as well as transdisciplinary and transformational research to explore food system transformation pathways.
3. Research funders should consider requiring the involvement non-governmental and research partners from fragile contexts in research about fragile contexts. This might help to set feasible and context-specific agendas for decision-makers in the Global North.
4. Decision-makers should consider that food system transformation toward sustainable and resilient FNS in fragile settings requires long timeframes of eight years or more.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2023.1107411/full#supplementary-material

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EDITED BY
Wolfgang Bokelmann,
Retired,
Berlin, Germany

REVIEWED BY
Pablo Pérez-Akaki,
Monterrey Institute of Technology and Higher Education (ITESM),
Mexico
Ravi Chambappa Nandi,
National Institution for Transforming India Aayog, India

*CORRESPONDENCE
Götz Bernhard Uckert
✉ uckert@zalf.de

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Consumer preferences and willingness to pay for dried traditional mangos from Kitui – A marketing analysis for Kenya and Germany

Götz Uckert[1]*, Andrea Cavicchi[1], Jil Soika[2], Custodio Matavel[1], Mirriam Mule[3], Salama Lerantilei[4], Losenge Turoop[5], Temi Mutia[6], Esther Ronner[7], Dagmar Mithöfer[2] and Stefan Sieber[1,2]

[1]Unit SusLAND, Leibniz Centre for Agricultural Landscape Research (ZALF), Müncheberg, Germany, [2]Department of Agricultural Economics, Thaer-Institute, Faculty of Life Sciences, Humboldt-Universität zu Berlin, Berlin, Germany, [3]Research Department, National Environment Trust Fund (NETFUND), Nairobi, Kenya, [4]Department of Food and Nutritional Sciences, Jomo Kenyatta University of Agriculture and Technology (JKUAT), Nairobi, Kenya, [5]Department of Horticulture, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya, [6]Head of Value Chains and Value Addition, County Government of Kitui, Kitui, Kenya, [7]Plant Production Systems, Wageningen University, Wageningen, Netherlands

The Kenyan mango value chain faces high post-harvest losses due to poor market access alongside a lack of storage technologies and processing facilities. Thus, using fruit processing methods, like solar drying, can enhance shelf life and help smallholder farmers access new markets, diversifying income and livelihoods. Nonetheless, the processing of both indigenous and grafted mango fruits is not a very common practice. This study was conducted to support product development targeting processing and marketing to link farmers to both local and export markets. Four independent consumer testing and sensory evaluation rounds on Kitui's dried mango flakes were conducted in Germany and Kenya. Data were collected via a group tasting by 31 randomly selected participants and an online questionnaire of 304 randomly selected participants. All participants were given samples of different varieties of dried mango flakes with and without additives. Results show that high-quality mango cultivars, like Ngowe, receive high hedonic scores without any additives (honey, sodium metabisulfite, or ascorbic acid). Some varieties positively respond to the treatments and achieve higher scores, e.g., Van Dyke or the indigenous variety Kikamba. The consumers testing in Germany show that extrinsic attributes, such as organic production, fair trade, cooperative, and sustainable labelled flakes open up new opportunities for farmers who aim for the export market. Against findings derived from German panellists, in Kenya, consumers do not show a higher willingness to pay despite having a positive attitude toward sustainability. Thus, the local market should focus on cost-reduction strategies rather than introducing standardisation.

KEYWORDS

smallholder farmers, post-harvest losses, market opportunities, consumer tasting panels, shelf life, processing facilities, solar dryers

1. Introduction

Mango (*Mangifera indica* L.) is a high-potential fruit that can be produced in many agro-ecological zones and, thus, across most of Kenya's territory. Due to its increasing demand in domestic, regional, and international markets, mango production has been deemed as a means to alleviate poverty in Kenyan households (Grant et al., 2015).

With a productive area of 49,098 ha and an annual raw mango production output ranging from 600,000 to 800,000 tons, Kenya is Africa's third largest mango producer (Grant et al., 2015). Since 2000, Kenya has witnessed an increase in mango production of almost 300% and exports of 400% (Fleming, 2020). In 2003, 14.4% of the total fruit export value was held by mango export alone. Yet, the export share of Kenya's mango production ranges between 1 and 4%, with most of the mango produced still consumed in the domestic market (FAO, 2004; Osena, 2011; Grant et al., 2015).

While mango production used to be limited to coastal areas, as of 2023, mango cultivars produced for export and local markets are found in 7 out of 8 provinces. As of 2012, within the national production of 754,702 tonnes, the Coast and Eastern regions cover 79% of the total national acreage and produce 596,215 tonnes. The Lower Eastern region, which comprises the counties of Makueni, Kitui, and Machakos, contributes 52% of this production volume (Grant et al., 2015). Thus, these three counties contribute strongly to the supply of mango exports. The production is dominated by small-scale farms, with 62,150 households relying on mango production as a source of income (Muthini, 2015).

Despite having become the key source of revenue for many small-scale farms since 2000 (accounting for the 22% of farm household income in the Eastern region), the local mango sector is an insecure market with unreliable buyers and with a value chain dominated by intermediate buyers, due to mango producing households' inability to meet market requirements (Muthini, 2015).

These challenges are associated with the fruit's high perishability and seasonality, which often leads to inadequate year-round supply, oversupply during harvest seasons, and extreme price fluctuations (Saúco, 2013). Additionally, the lack of processing facilities, adequate transportation means, and other infrastructure necessary to access city markets results in high post-harvest losses of 30–40% (Mongi et al., 2013). Even when the infrastructure is present, the long distances between farms and marketplaces lead to product spoiling and high transportation costs, which can reach 77% of the product value (Nzioki, 2013; Muthini, 2015). Therefore, it is necessary to elaborate and assess available value-addition strategies that can address the low shelf life of the fruit and the lack of access to markets of choice (Kennedy, 2015; Tobin et al., 2016; Musyoka et al., 2020).

Drying is one of the most widely utilised methods of food preservation to address these constraints. In tropical and sub-tropical countries, drying is generally applied through solar energy, the cheapest and easiest method to implement (Akoy et al., 2008). This process is done to remove water to a level where microbial spoilage and deterioration reactions are greatly minimised (Akpinar and Bicer, 2004), resulting in longer shelf-life, reduced space needed for storage, and lighter weight to transport, which can facilitate and reduce the costs of exporting the product (Ertekin and Yaldiz, 2004; Naz, 2012; Mongi et al., 2013). Moreover, dried fruits are not subjected to the same strict market requirements that fresh fruits must respect since they can have various flavours, shapes, textures, and properties depending on the processing (Wong et al., 2020). Processed dried mango is an added-value product that can be sold with a higher profit margin, improving the income and livelihoods of rural households (Grant et al., 2015; Wong et al., 2020).

In Kenya, where the retailing of fresh fruit is preferred to processed, dried mango is a novel prodcut. Even for export, only 6% of local Kenyan farmers undertake this value-adding strategy, with, in total, only 2% of all mango grown in Kenya being processed (Musyoka et al., 2020). Thus, despite being Africa's largest mango producer, Kenya still plays a marginal role in the European dried mango import market. One main European consumer, Germany, sees its dried mango imports coming principally from Burkina Faso and South Africa [Centre for the Promotion of Imports from Developing Countries (CBI), Ministry of Foreign Affairs, 2021]. This can be seen as a missed opportunity for Kenya's smallholders, who rely more on subsistence production and farm gate purchases.

On the other hand, Germany is a fast-growing dried mango market, thus in 2020 surpassing European imports the UK as the main dried mango buyer. While retailing was traditionally relegated to specialised stores, now dried mango is found in most mainstream supermarkets [Centre for the Promotion of Imports from Developing Countries (CBI), Ministry of Foreign Affairs, 2021]. In 2020, 7,000 tons of dried mango were imported across Europe (with an increasing trend of import volume of 10–12% between 2018 and 2022). As the main export market of focus, the UK and Germany provide great opportunities, especially for fair trade and organic certified dried mango [Centre for the Promotion of Imports from Developing Countries (CBI), Ministry of Foreign Affairs, 2021]. The great success of fair trade and organic products can be attributed to the great relevance that these topics hold for European consumers. Ethical production, food safety, and marketing characteristics along the value chain, among others, play an essential role in consumer choice (Badar et al., 2015). These non-sensory attributes (defined as extrinsic attributes) are not part of the physical characteristics of the product (i.e., intrinsic attributes, such as taste, sweetness, aroma, consistency, etc.), yet they correspond to marketing-related attributes that consumers evaluate during the purchasing process (Badar et al., 2015; Rondoni et al., 2021). These are relevant to the consumer and their preferences.

The study was done in the frame of the EU (LEAP-Agri, 2017) project "STEP-UP." Export options for mango were assessed within a bundle of sustainable intensification (SI) and market linkage (ML) strategies to enable small farm enterprises (SFEs) to step up toward food and nutrition security, sustainable development, and income generation. The County Government of Kitui, in close collaboration with several key development partners, has identified value addition as one of the critical missing links necessary for sustainable mango farming in the county (CGoKTI, 2020). As such, 335 individuals were randomly selected in Germany and Kenya to evaluate the sensory attributes of Kitui's dried mango flakes. The overarching goal of the surveys is to provide an initial contribution to the market development of dried mango in Kenya (for local consumption) and Germany (for export). This will be done by answering three research questions:

1. How do Kenyan and German consumers differ in terms of intrinsic preferences toward different types of dried mango flakes produced in Kitui?

2. Do German and Kenyan consumers respond to the extrinsic attributes similarly? How do extrinsic attributes affect their willingness to pay?
3. Could varieties and processing methods be identified to meet the export or local market best?

More specific questions need to be formulated after further establishing the product in Kenya. Do more experienced German consumers assess the intrinsic attributes more critically and expect the product to have a fruity flavour, shiny colour, and sweet taste to receive higher hedonic scores than the new consumers in Kenya? Will we find extrinsic attributes with a similar impact on the WTP in both countries, even considering the high difference in wealth and age cohorts of the population?

2. Methods

Through a series of workshops, STEP-UP co-designed the quality management and applied training on mango production and processing, as well as on marketing and market access of mango and mango value-added products, with a special focus on mango flakes. The STEP-UP Project with NETFUND and JKUAT, in close collaboration with the initiative at the County Government of Kitui, organised the trainings. From an initial two solar dryers in 2019, an additional 11 solar drying units were added step-by-step through 2021, which builds the basis for the sampling of the flakes for testing in the surveys (KVTT, GAPA, and KAPA). Between October 2019 and April 2021, product consumer testing and sensory evaluations were conducted after two seasons of mango drying activities, including processing through solar drying and commercialisation of locally produced mango flakes. The sampling methods were limited by the COVID-19 pandemic and related restrictions. Consequently, we could not approach randomised consumers at the site of markets or events to provide the mango flakes tasting samples. Nevertheless, 335 panellists in Germany and Kenya contributed to improving market strategies for export and local markets.

The Kenyan (KAPA) and German (GAPA) surveys use a methodology for developing marketing strategies that focus on the values of consumers comprising both particular interests for themes linked to the macro area of sustainability while also targeting a more pragmatic orientation (nutritional value, taste). The marketing strategy is then determined under the principle of compatibility (or fitting in with existing values, past experiences, and needs of potential adopters).

The survey on Kitui mango specifics (KVTT) carried out an analysis to establish the most appropriate treatment for each variety, enhancing the value-adding component. Each treatment has the property to enhance a specific intrinsic attribute and a specific treatment is not a panacea for all mango varieties.

2.1. Study area

The Kenyan surveys were conducted in the Kenyan counties of Nairobi, Kiambu, and Kitui, whereby the KVTT was conducted in the JKUAT, Juja/Nairobi only. Kitui County, one of 47 counties in Kenya, is situated 160 km east of Nairobi City. It lies between latitudes 0°10 South and 3°0 South and longitudes 37°50 East and 39°0 East. Based on its area cover, Kitui is the sixth-largest county in the country and covers an area of 30,429.5 km^2, which includes 6,302.7 km^2 occupied by Tsavo East National Park. The county has eight (8) sub-counties: Kitui Central, Kitui East, Kitui Rural, Kitui South, Kitui West, Mwingi Central, Mwingi North, and Mwingi West (Figure 1). According to the 2019 population census, Kitui has a population of 1,136,187 (Kenya National Bureau of Statistics, 2019). The main economic activity in Kitui County is agriculture, contributing to food security and generating 87% of rural household income. One of the main cash crops grown in the county is mango, with 81–100% of farmers engaged in the mango value chain (Ministry of Agriculture, Livestock, Fisheries and Co-operatives, 2021). Nairobi and Kiambu County were also selected for the study due to their huge markets. These two counties host a large working population of all ages with differing education levels, income levels, and eating habits (Ministry of Agriculture, Livestock, Fisheries and Co-operatives, 2021).

Together with the United Kingdom, Germany represents half of the European market for dried mango. Germany is a particularly attractive market for organic dried mango as the country is the largest European market for organic food. Further, sugar-free and preservative-free dried mango sales are increasing [Centre for the Promotion of Imports from Developing Countries (CBI), Ministry of Foreign Affairs, 2021]. In Europe, at least 80 percent of the dried fruits end up in breakfast cereals and the confectionery industry [Centre for the Promotion of Imports from Developing Countries (CBI), Ministry of Foreign Affairs of the Netherlands, 2014]. Hence, dried fruits sold

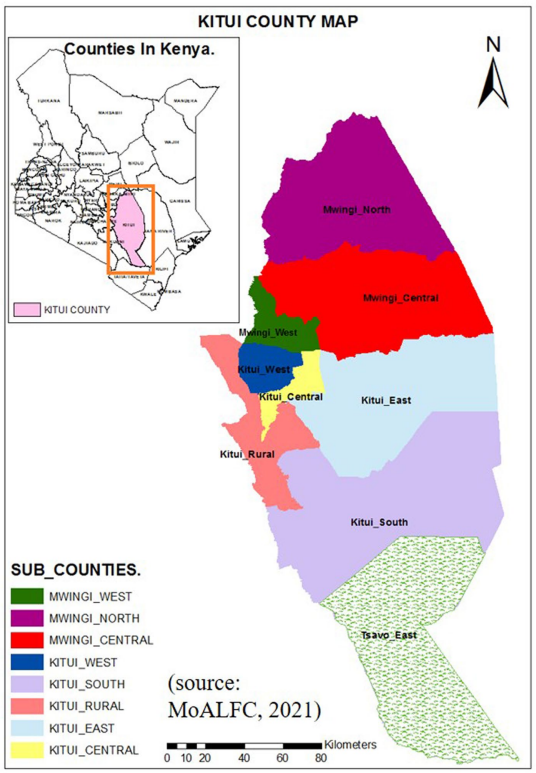

FIGURE 1
Map of Kitui county showing the eight sub-counties (Ministry of Agriculture, Livestock, Fisheries and Co-operatives, 2021).

as a snack in Europe can generally be categorised as niche products. Tropical dried fruits, like mangoes, bananas, and pineapples, are among the rare dried fruits increasingly popular as healthy snacks [Centre for the Promotion of Imports from Developing Countries (CBI), Ministry of Foreign Affairs of the Netherlands, 2014].

2.2. The Kenyan varieties and treatment testing

The Kenyan varieties and treatment testing (KVTT) was conducted to determine the best-performing combination of mango variant and treatment from a mere intrinsic standpoint. It involved 31 students from the food and nutrition science department at the Jomo Kenyatta University of Agriculture and Technology (JKUAT) acting as semi-trained panellists, following an experimental research design with a 4×6 factorial arrangement. Provided with six varieties of dried mango flakes produced in Kitui Central and processed at the Sun Sweet solar drier of Ithiiani, participants were asked to evaluate the sensory attributes (i.e., colour, aroma, taste, chewiness, sweetness, and overall impression) of each variety through a questionnaire utilizing a 9 point hedonic scale ranging from the extreme like to extreme dislike. The meaning of each attribute was explained to the participants to avoid interpretation biases. No information regarding demographics (except the age and sex of participants) or consumer behaviour was collected. The testing aimed to address the range of intrinsic characteristics of Kitui's dried mango.

The tested mango varieties are Ngowe, Apple, Van Dyke, Boribo, Kent, and Kikamba. Each variety was presented to the panellists in 4 different samples (one control with no treatment, one sample treated with a solution of ascorbic acid, one treated with a solution of sodium metabisulfite, and one with a honey water solution). The participants received potable water for mouth rinsing between tests to avoid tasting disturbances.

The consumer testing results were analysed and compared between samples through an analysis of variance (ANOVA) at a significance level of $p \leq 0.05$ using the IBM statistical package SPSS 23.0. The means were compared using the Tukey's-*b* test whenever the treatment effects were significant.

2.3. The German acceptance and preference analysis

The German acceptance and preference analysis (GAPA) was developed in Berlin, the German capital. Due to the COVID-19 pandemic, conducting a physical consumer panel was impossible, so it was decided to design a home-use test that could be carried out remotely. The developed, easy-to-apply, research tool was distributed in Berlin and mailed to potential untrained consumers in Germany (Soika, 2022). The hand-out and mail contained three samples of mango flakes to evaluate intrinsic and extrinsic dried mango attributes. It sought to identify the correlation between demographic factors (age, sex, income, occupation), consuming behaviour related to dried mango (frequency of purchasing and consumption), label-certified products (organic, natural, fair trade), values, and willingness to pay for Kenyan produced dried mango. GAPA was conducted in a two-stage survey of untrained panel settings. The participants of both panels were a convenience sample recruited through the network of the research team, which – due to Covid-19 – was the only feasible option to carry out research in person. Participants were mostly young people with academic backgrounds and not necessarily regular consumers of dried products. A remote home-use test for self-administration was designed and, for each round of testing, panellists received the samples and the evaluation form by mail. The sensory acceptance and preference test was devised following Lawless and Heymann (2010) and prepositioned to Nguyen and Wismer (2019). The acceptance test measures consumer attitudes toward a particular product nuanced by measurement of specific product attributes (Lawless and Heymann, 2010) and, in the present case, provides insights about the acceptance of the entirety of the mangos. For the WTP analysis, the method of "Price Sensitivity Meter" (PSM) was applied according to Van Westendorp (Chatterjee et al., 2015; Weinrich and Birgit Gassler, 2021) to determine the optimum price point of which consumers intend to buy the dried mango products.

First, the Preparatory Consumer Testing (PCT), performed in January and February 2021, involved 113 untrained panellists who assessed the intrinsic attributes of 3 different dried mango samples: Kikamba half ripe, Kikamba full ripe (both produced in Kitui during the STEP-UP project during the harvest season 2019/2020 and without additives), and a brand widely offered in German supermarkets, hereafter referred to as *market reference* (which is treated with sodium bisulfite).

Second, the MCT (Major Consumer Testing) was conducted on 97 untrained panellists to investigate consumer preferences and willingness to pay, utilizing an untreated Apple mango (control) sample without additives, Kikamba Half Ripe mango fingers (produced in Kitui, also without additives), and again the same market reference treated with sodium bisulfite.

Each sample's intrinsic attribute (i.e., colour, aroma, taste, chewiness, sweetness, sourness, and overall impression) was evaluated by respondents using a 9-point hedonic scale ranging from the extreme like to extreme dislike.

Both surveys were conducted using the online tool Survey Monkey. The consumer acceptance and preferences analysis was done with IBM SPSS® Statistics version 27. Dummy variables for influential consumer liking variables were created to determine differences between consumer groups. These dummies include (a) Age (below and equal or above 35 years); (b) Ecological brand buying behaviour; (c) Sustainable store buyers; (d) Regular and non-regular consumers; (e) Regular and non-regular buyers; (f) Market reference buyers and non-buyers; and (g) Fair trade brand buyers and non-buyers. Further analyses on determinant factors like income, and clusters to build targeted communication strategies (Nandi et al., 2016) are not presented in this paper.

Each dummy related to consuming behaviours was created by dividing the population into two categories based on the frequency of consumption (where people answering the question "how often do you buy food that..." with "often" or "always" were assigned to the population adopting the consuming behaviour). Statistical significance was analysed through the ANOVA function at a significance level of $\alpha = 0.05$.

2.4. The Kenyan acceptance and preference analysis

Kenyan acceptance and preference analysis (KAPA) follows the same methodological design as GAPA to assess the possible degree of influence of Kenyan consumers' values, knowledge, and background on the intrinsic attributes, perception, and willingness to pay for dried mango. This part of the study serves mostly as a preliminary test to have an initial idea regarding the openness of Kenyan consumers to relatively cheap-to-produce varieties. It also served as a baseline to determine if the degree of influence of extrinsic factors is similar to the German case.

It employs a data set from a questionnaire administered online through Survey Monkey in three waves of surveys conducted in September and October 2021 of a 100-respondent sample. The stratified random population sample consists of members of NETFUND staff in Nairobi, JKUAT students in Kiambu, local mango producers in Kitui, and residents in Kitui. The respondents, who were not trained panellists, received dried mango samples and were asked to complete a questionnaire using Survey Monkey. Demographic information, such as age, gender, education, occupation, income, consumption and purchasing habits (concerning extrinsic attributes such as organic, fair trade, sustainable, and healthy products), was gathered and processed to conduct a regression analysis.

The solar-dried mango flake samples, consisting of full ripe Apple Mango and Kent Mango, were produced and purchased by a local mango processing facility small holder in Kitui Central without additives. Each sample's intrinsic attribute (i.e., colour, aroma, sweetness, taste, etc.) was evaluated by respondents using a 9-point hedonic scale ranging from the extreme like to extreme dislike. The testing round was conducted with the panellists not knowing about the dried mango's extrinsic attributes.

The data collected was treated and analysed using IBM SPSS® Statistics version 27. A set of dummy variables was created to divide the sample population into different sub-sets as independent variables, differentiating the degree of acceptance for various sample categories (and to find possible correlation links between consumer groups and appreciation of dried mango samples in light of extrinsic attributes). The dummy variables (all dichotomous or binary) were created to divide the population by (a) Age, differentiated in adults (>35) and youth (<=35); (b) Degree of ecological footprint awareness; (c) Dried mango purchasing habits; (d) Degree of preferences for organic products; (e) Degree of preferences for fair trade products; (f) Degree of preferences for socially sustainable products; (f) Degree of preferences for healthy products; (g) Degree of preferences for natural products; and (h) Budget constrained buyers and consumers without budget constraints.

Each dummy related to consuming behaviours was created by differentiating the population into two categories based on the frequency of consumption (where people answering the question "how often do you buy food that ..." with "often" or "always" being assigned to the population adopting the consuming behaviour). The statistical significance between variables ($p < 0.05$) was determined under the *T*-test and the Mann–Whitney *U* test through the one-way Analysis of Variance (ANOVA).

The COVID-19 pandemic affected the implementation of the study as gatherings were banned and major cities had lockdowns. These prevented researchers from moving from urban areas to rural areas.

2.5. Datasets used

2.5.1. Kenyan varieties and treatment testing

The Kenyan Varieties and Treatment Testing were conducted with a group of 31 semi-trained mango consumers, of which 18 were male and 13 female, all belonging to the age class of the youth (<35 years), with a mean age of 25 years. All participants were students of food and nutrition science at JKUAT. No other information regarding the sample population characteristics was collected.

2.5.2. German acceptance and preference analysis

2.5.2.1. Preparatory consumer testing

The Preparatory Consumer Testing (PCT) of the German Acceptance and Preference Analysis, conducted in January and February 2021, employed 113 untrained consumers, 67 of which were females (59.3%) and 46 males (40.7%), with a mean age of 32 years (with variability that ranges from 5 to 70 years), where the majority of panellists were in their mid-twenties and early thirties (Table 1). No information on education, occupation, and income was collected during the PCT.

TABLE 1 Gender and age of PCT and MCT participants in Germany (GAPA): percentage and N.

German surveys	PCT	PCT	MCT	MCT
Variable	Percentage (%)	Absolute frequency (*N*=)	Percentage (%)	Absolute frequency (*N*=)
Gender	100	113	98.9	93
Male	40.7	46	33	31
Female	59.3	67	64.9	61
Diverse	–	–	1.1	1
Age	100	113	100	94
35 or younger	74.3	84	85.1	80
36 or older	25.7	29	–	–
Between 36 and 57	–	–	8.5	8
Over 57	–	–	6.4	6

2.5.2.2. Main consumer testing

The Major Consumer Testing conducted 4 months after the PCT included 94 panellists (61 females, corresponding to 65% of the sample population, 31 males, equal to 33% of the sample, and one non-binary) (Table 1). Most panellists were in their mid-twenties and early thirties, with an average age of 32 years (similar to the PCT).

Most of the sample population had an academic degree, with 34% holding a Bachelor's degree, 30% a Master's degree, and 37% being enrolled in a university. Almost half of the sample population was employed, with the vast majority having an income range in the lower half of the spectrum (Table 2).

2.5.3. Kenyan acceptance and preference analysis

The rounds of testing in the Kenyan Acceptance and Preference Analysis included 100 respondents from Nairobi, Juja, and two sub-counties of Kitui County (Kitui Central and Mwingi West). The average age was 25 years (with a variability that ranges from 18 to 52 years), with the large majority being in their early to mid-20s, 40.8% being female, and 58.2 male (with one person describing themself as non-binary). Adults (those older than 35) made up only 10% of the sample (Table 3).

Most of the sample had concluded their education in a tertiary institution (90%), 62% of the respondents were students, 23% were employed, 4% were unemployed, and 9% described themselves as self-employed (Table 4). These figures provide a first explanation regarding the income range of the sample, where 50% of the respondents collocated themselves at the lower end of the income spectrum, and only 24% earned more than 30,000 KES (KES = ISO code for Kenyan Shillings) per month.

TABLE 2 Socio-demographics of MCT (GAPA): percentage and N of education, occupation and income.

Variable	Percentage (%)	Absolute Frequency (*N*=)
Education	98.9	93
Secondary School	3.2	3
College, no degree	11.7	11
University, no degree	16	15
Bachelors' graduate	34	32
Masters' graduate	29.8	28
Promotion	4.3	4
Occupation	97.9	92
Student	4.3	4
University Student	37.2	35
Employed	44.7	42
Freelancer	11.7	11
Income (per month)	97.9	92
Less than 1,000 €	29.8	28
1,000–1,499 €	24.5	23
1,500–1999 €	10.6	10
2000–2,999 €	20.2	19
3,000–4,999 €	8.5	8
5,000 € and more	4.3	4

TABLE 3 Kenyan sample population (KAPA), N and percentages for gender, age and education classes.

Variable	Percentage (%)	Absolute frequency (n=)
Gender	100	98
Male	58.2	57
Female	40.8	40
Non-Binary	1	1
Age	100	100
34 or younger	91	91
35 or older	9	9
Education	100	98
Secondary	8.2	8
Tertiary*	91.8	90

*Formal post-secondary education, including public and private universities, colleges, technical training institutes, and vocational schools.

3. Results

3.1. Sensory evaluation under different treatments and intrinsic attributes assessment (KVTT)

The sensory evaluation of each mango flake variety under no treatment shows that Ngowe is the mango with the highest quality, according to the trained panellists, followed by Van Dyke and Boribo. In contrast, Kikamba is rated as the lowest quality variety (yet not rejected by the panellists), followed by Kent and Apple (Table 5).

Observing the hedonic scores given by 32 panellists to 6 mango flakes varieties treated with sodium metabisulfite, ascorbic acid, and honey, it emerges that these treatments do not significantly increase the overall acceptance of Ngowe (where the treatment negatively affects the hedonic score), Apple, Van Dyke, or Kent. On the other hand, sodium metabisulfite enhances the degree of liking of Boribo. In contrast, honey significantly affects the degree of enjoyment of varieties like Kikamba and Boribo (but to a lower extent compared to sodium metabisulfite for Boribo). Additionally, the variation in hedonic score between control Van Dyke and Van Dyke treated with honey suggests that honey increases the degree of enjoyment of the variety. Still, this difference is insignificant ($p > 0.05$), similar to Kent treated with ascorbic acid. Honey-treated dried mango flakes had the highest score on overall acceptability, followed by sodium metabisulfite, control, and ascorbic acid. The study also shows that the use of additives has no significant effect on the taste, sweetness, and chewiness (or mouthfeel) of four mango varieties: Ngowe, Apple, Van Dyke, and Kent (Table 5).

3.2. Germany's acceptance and preference analysis

3.2.1. Preparatory consumer testing

Figure 2 gives an overview of the last time of purchase of the two German surveys: In PCT 52 respondents (46%) never purchased dried

TABLE 4 Kenyan sample population (KAPA) divided in occupation classes and related gross monthly income in KES.

	Gross Monthly Income				
Occupation	Less than KES 10,000	Between 10,000 – 30,000	Between 30,000-50,000	Above 50,000	Total N
Pupil	1	0	0	0	1
Student	45	14	2	0	61
Self employed	3	4	2	0	9
Employee	0	6	5	12	23
Unemployed	1	2	1	0	4
Total N	50	26	10	12	98

KES, ISO code for Kenyan Shillings.

TABLE 5 Kenyan hedonic test scores* of dried mango flakes' overall acceptance as affected by the variety and treatment (KVTT); means with different superscripts$^{(x)}$ within a column and with different subscript$_{(x)}$ within a row are significantly different (LSD, $P<0.05$), and values are presented as mean±SD.

Variety	Treatment				
	Control	Sodium metabisulfite	Ascorbic acid	Honey	Sig. level row
Ngowe	$7.23 \pm 1.56^{b}_{b}$	$6.39 \pm 1.75^{ab}_{ab}$	$6.13 \pm 1.78^{bc}_{a}$	$6.77 \pm 1.15^{abc}_{ab}$	*
Apple	$5.90 \pm 1.94^{ab}_{a}$	$6.03 \pm 1.80^{a}_{a}$	$5.48 \pm 2.01^{ab}_{a}$	$5.84 \pm 1.66^{a}_{a}$	ns
Van Dyke	$6.65 \pm 2.09^{ab}_{a}$	$7.35 \pm 1.38^{b}_{a}$	$7.00 \pm 1.77^{c}_{a}$	$7.42 \pm 1.26^{c}_{a}$	ns
Boribo	$6.65 \pm 1.84^{ab}_{ab}$	$7.27 \pm 1.60^{b}_{b}$	$5.74 \pm 2.28^{abc}_{a}$	$7.06 \pm 1.91^{bc}_{b}$	*
Kent	$5.81 \pm 1.94^{ab}_{a}$	$6.58 \pm 1.18^{ab}_{a}$	$5.61 \pm 1.76^{abc}_{a}$	$6.16 \pm 1.66^{ab}_{a}$	ns
Kikamba	$5.00 \pm 2.22^{a}_{ab}$	$5.55 \pm 2.05^{a}_{ab}$	$4.68 \pm 2.18^{a}_{a}$	$6.13 \pm 1.74^{ab}_{b}$	*
Sig. level col.	*	*	*	*	

$N = 31$, * = Significant at 5% level and ns, non-significant ($p > 0.05$). *Hedonic scale from 1 to 9, 1 = I dislike extremely, 2 = I dislike very much, 3 = I dislike moderately, 4 = I dislike slightly, 5 = Neither like nor dislike, 6 = I like slightly, 7 = I like moderately, 8 = I like very much, 9 = I like extremely (Lerantilei, 2022).

FIGURE 2
Germany's acceptance and preference analysis (GAPA) last purchase, frequency of consumption (PCT and MCT), % of respondents.

mangos, 11 respondents (9.7%) bought mangos within the last month 23 panellists (20.4%) purchased them over a month ago, 20 respondents (17.7%) over a year ago, and 7 (6.2%) indicated that they could not remember the last time of purchase or that it was too long ago. In the sample evaluation, there were no statistically significant differences between frequent consumers of dried mango and those who do not buy or consume it, in overall liking and mango taste scores on the provided mango samples.

The market reference scored the highest means in every category. The largest discrepancy is displayed for overall liking, where the market reference has a mean (M) of $M = 7.65$ (Supplementary Table A.2 and Figure 3). The means of the Kenyan varieties for overall liking, mango taste, colour, and hypothetical purchase frequency are quite close for both full-ripe and half-ripe (Figure 3).

The results of the first consumer panel (without extrinsic attributes mentioned to the panellists) show that younger and female

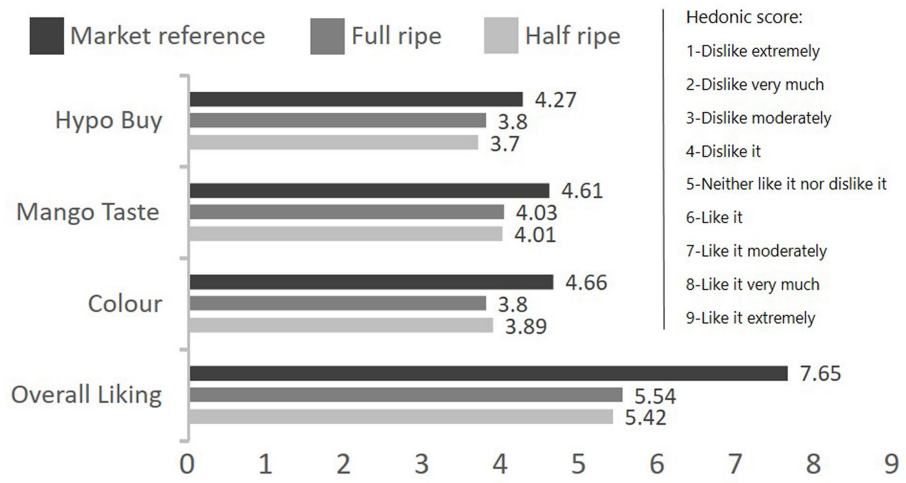

FIGURE 3
Preparatory consumer testing (PCT) means of dried mango attributes (9 point Likert scale) (GAPA).

consumers are those who purchase and consume dried mangos most often (Supplementary Table A.2). The greatest difference in sensory evaluation between the Kikamba varieties and the market reference can be found in the attributes of colour and mango taste (where the market reference displays higher liking). The mango taste of the Kikamba varieties was evaluated slightly better by ecological brand buyers than by regular brand buyers, yet not by a significant margin. Furthermore, ecological brand buyers evaluated the mango taste of the treated market reference as slightly inferior. In total, 88 panellists preferred the market reference, 11 liked the half ripe Kikamba most, and 11 the full-ripe Kikamba (Supplementary Table A.2).

3.2.2. Major consumer testing

Figure 2 also gives an overview of the last time of purchase for the 94 MCT respondents: 33% never bought dried mango, 26.6% stated that the last time they purchased was over a month ago; further 7.4% purchased dried mango last week, 12.8% last month, 7.4% purchased it over a year ago, and 12.8% cannot remember or the purchase was too long ago to remember. The results show no difference in acceptance of the mango samples between the frequent and non-frequent purchasers of dried mango. Therefore, the respondents are treated equally.

The market reference shows the highest score for overall liking with a mean (M) of $M = 7.24$ on the 9-point hedonic scale compared to the Kenyan variants with a mean score of $M = 6.85$ (Apple) and $M = 5.81$ (Kikamba) (Figure 4).

Please find results of statistical analyses displayed in Supplementary Tables A.3, A.4:

No statistical significance was found between the groups of younger and older consumers. The Kikamba variant has the lowest means, followed by the Apple variant. The market reference shows the highest values and is slightly preferred by younger consumers, while older respondents prefer the Kikamba mango and market reference.

Ecological brand buyers do not significantly differ in overall liking compared to regular brand buyers. No significant difference was detected between the groups of infrequent and frequent buyers, market reference and various brand buyers, or between consumers and non-consumers of dried mango.

Consumers with either high or low scores for ecological awareness both prefer the market reference. However, consumers with a high score on ecological awareness rank the Apple mango second ($M = 6.9$) and Kikamba last ($M = 5.7$), whereas consumers with a low score rank the Kikamba mango second ($M = 6.0$) and Apple last ($M = 5.0$).

Consumers with a high awareness of fair-trade show overall higher means for liking mangos across all variants. The group with high awareness shows the highest mean of all 68 groups for the Apple mango ($M = 7.37$), which is only 0.36 points lower than the mean of the market reference ($M = 7.73$). The group' means differ only statistically for the market reference; it is close to significant for the Apple variant ($p = 0.56$).

The Apple mango has the highest mean for mango taste, with a value of $M = 5.54$, followed by the market reference, with a mean of $M = 5.47$. Kikamba mango has the lowest value for this attribute, with a value of $M = 4.86$. Yet, Kikamba mango shows the lowest means followed by the market reference and Apple mango with higher means.

The reference mango has the highest mean, with $M = 6.27$ for the attribute colour, closely followed by Apple mango with $M = 5.94$. The brown Kikamba mango has the lowest value, with $M = 3.85$. Consumers with a high awareness of fair food production have a higher overall liking for the colour of all variants. The hypothetical purchasing frequency is the highest for the market reference, with a mean of $M = 4.46$. The mean for Apple is slightly lower at $M = 4.11$, followed by Kikamba at $M = 3.57$. No relevant significance for hypothetical purchasing frequency is found for all other consumer groups.

Following the tasting, respondents were asked to state which sample they preferred without any further information: 50% of the respondents chose the market reference, 29.8% picked the Apple mango, and 20.2% the Kikamba mango (Figure 5). After assessing the intrinsic attributes, the panellists were informed about the extrinsic attributes of the samples: the Kenyan mangos

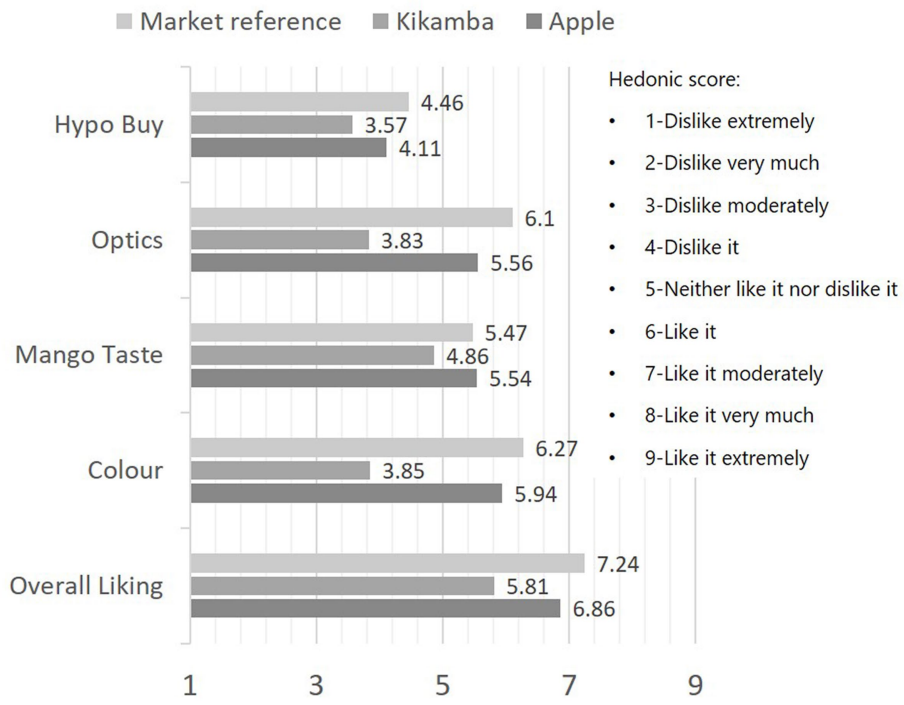

FIGURE 4
Major consumer testing (MCT) means of dried mango attributes (GAPA).

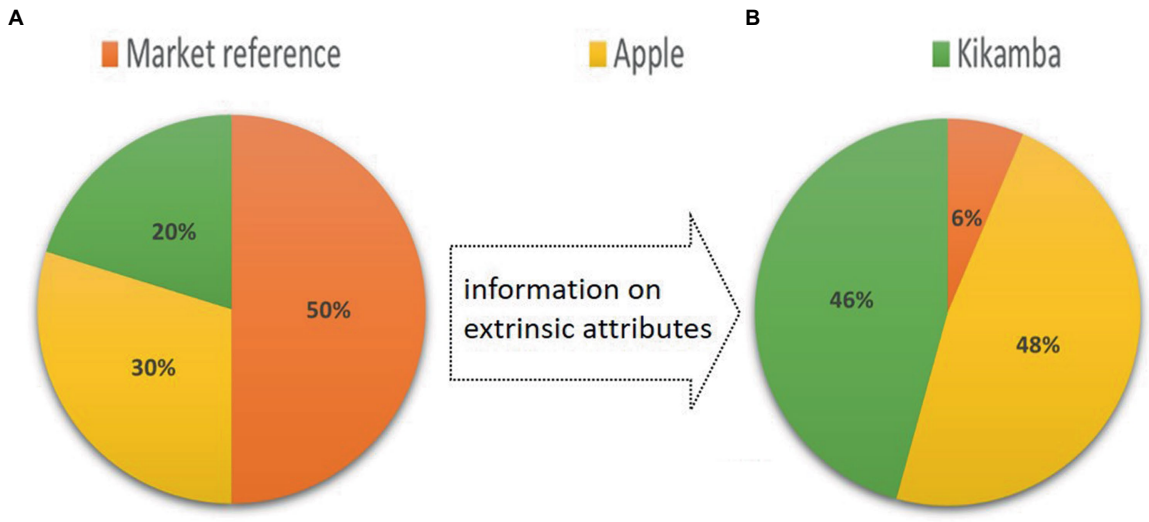

FIGURE 5
Major consumer testing preference shares without **(A)** and with **(B)** extrinsic attribute information (GAPA).

were characterised by no additional treatments, ecological production, and fair-trade certification, while there was a sodium bisulfite treatment and no such certification for the market reference. With that information given, 43.6% of the former respondents who previously preferred the market reference mango changed to the Kenyan variants, resulting in 47.9% of the panellists preferring the Apple mango and 45.7% the Kikamba mango (Figure 5).

3.3. Sensory evaluation results from Kenya (KAPA)

Among the untrained panellists participating in the KAPA consumer testing, only a small fraction, $n = 9$ (13%), had bought dried mango within the last month. The majority of the sample had never bought dried mango before (59.4%), while the rest had bought it a long time ago (17.4%) or within the last year (10.1%). Among the

reasons why respondents do not buy dried mango products regularly, the most chosen response was "unavailability," followed by the "preference for fresh produce."

All respondents liked the samples (from "slightly" to "extremely") with few exceptions. Kent received more negative scores than the Apple variety, with greater minimum scores for all the liking factors. In terms of overall appreciation, Apple is slightly more preferred. The Apple variant is particularly appreciated for taste and aroma (sweet taste), and the Kent variety for the colour (appearance or look) (Supplementary Table A.5).

Analogous to the investigations of extrinsic attributes of dried mangos sold in Germany, the influence of motivation or attitude on the evaluation of the dried mango flakes was tested in the survey in Kenya. For this purpose, the respondents were divided into two groups based on their answers – which were used as a dummy variant to work out differences. Both adults and youth have a slight preference for the Apple variant. The sample population younger than 35 gave higher average scores to both variants than the adults: 1.73 and 0.45 average points, respectively. Statistical significance was found for different Kent attributes, showing a higher predisposition of the youth for the Kent variety (Supplementary Tables A.7, A.8).

When analysing the results with respect to gender, no statistically significant difference between males and females emerged. Yet, the results show that females tend to give higher scores for all the liking factors and, thus, the overall impression of both variety samples (Supplementary Tables A.7, A.8). Males, on the other hand, gave more negative scores (even from "moderate" to "extreme") to the Kent variant and a few slightly negative scores to the Apple variant. Statistically significant differences were found between the groups of regular and non-regular mango flakes buyers concerning Kent variety overall impression ($p = 0.016$), aroma ($p = 0.020$), chewiness (0.043), and sweetness (0.025), with regular buyers providing significantly greater average scores. Additionally, regular buyers provide higher scores for every sensorial category for Kent and Apple varieties (Supplementary Table A.6).

Against results from the GAPA we checked the possible impact of extrinsic attributes by looking at the correlation between the degree of overall liking and participants buying habits. We found among created consumer groups that only within those who were oriented toward natural products showing significant differences ($p < 0.05$). For groupings regarding ecological footprint (eco-friendly) or fair-trade awareness, consumer behaviours seeking for organic, and local (K0) products, any statistically significant differences ($p < 0.05$) were revealed (Supplementary Tables A.7, A.8).

When comparing natural product buyers and non-natural product buyers, statistically significant differences are found between the two groups concerning Apple variety overall impression ($p = 0.022$), where natural buyers give a significantly higher average score (8.19 vs. 7.68) (Supplementary Tables A.7, A.8). According to the average scores for each variety, Kent colour is the only characteristic deemed better than Apple by both groups.

Looking at the sample population portion who always or often buys healthy products, compared to those who do not or do it seldomly, there is a statistically significant difference ($p = 0.021$) concerning the degree of appreciation of Kent mango colour, with non-healthy buyers ($M = 8.56$) giving a significantly higher mean score (against an $M = 7.86$ from healthy buyers). This population also gave higher scores to the aroma, sweetness, sourness, chewiness, and overall impression. Kent's worst attribute, according to non-healthy buyers, was taste, while for healthy buyers, it was the aroma (Supplementary Tables A.7, A.8).

3.4. Willingness to pay comparison between Germany and Kenya

In Germany, the Kikamba and Apple mango purchased at around 3 euros would be considered a good offer (with 5.50 euros considered too expensive and 1.76 euros too cheap, whereas the right price for the market reference is 2.27, with 4.52 too expensive and 1.38 too cheap), with the max expenditure set at around 4.20 euros for both varieties. Consumers with a higher awareness of fair-trade exhibit a higher mean for the expensive price point at which they would still buy the dried mangos compared to those with a middle to low awareness. On the other hand, figures from the Kenya survey show that the willingness to pay is much lower, even after knowing the extrinsic attributes, with no statistical significance in the willingness to pay among the dummy variables created. The willingness to pay was then evaluated based on the income classes to out rule the lack of finances as the main motivation.

More than half of the respondents of all income classes would pay between 40 and 80 cents for 100 g of dried mango, 25% between 80 cents and 1.20 euros, 14% between 1.20 and 1.65 euros, and only 7.9% would pay the price ranging between 1.65 and 2.05 euros. The portion of the population at the lower end of the income spectrum gave the highest average scores for the overall impression of both mango varieties. However, this did not have a noticeable positive effect on their willingness to pay.

Notably, the willingness to pay does not increase significantly for higher income classes, even though more people within the class between 30,000 and 50,000 KES per month report a willingness to pay a slightly higher price, although this difference is not statistically significant, with $p > 0.05$.

4. Discussion

4.1. Comparing the Kenyan and German consumer groups (KAPA and GAPA)

According to overall impression rates, it is possible to establish that the Kenyan population does not have a strong preference for one specific variant, even though the Apple variety shows higher means, especially for the sweetness, taste, and overall impression. On the other hand, according to the PCT results from Germany, the market reference surpasses the scoring of both Kenyan varieties. In Germany, the mango flakes market is already established and consolidated; hence almost half of the panellists in the PCT have consumed or purchased dried mango in the recent past or within the month before the assessment (unlike Kenya, where this sub-group shrinks to 13%). In the MCT, 15% of the respondents frequently purchase dried mango (once or more than once per month). The market reference (which is already popular in German grocery stores) is deemed as the best under unknown extrinsic attributes when compared with the new Kenyan varieties (namely Apple and Kikamba, the latter of which, as the KVTT showed, is at the lower end of the quality spectrum).

On the other hand, in the KAPA, Kent and Apple receive very high scores for their overall impression, surpassing the acceptance of the market reference in Germany and the scores of the same varieties evaluated in the KVTT. The Apple variant is particularly appreciated for taste, sweetness, and aroma, while the Kent receives very high scores for its colour. Such attributes are essential for product acceptance (Leng et al., 2017) since they are the primary concerns of the consumers (Khandelwal et al., 2017).

It is impossible to assess whether these higher scores translate into a greater predisposition by Kenyans to enjoy local mango varieties or if the high score is again due to a lack of access to dried mango and, hence, they do not have a baseline for assessing the sample characteristics as in Germany. The latter would seem more likely, considering that the semi-trained panellists from the KVTT were much more moderate in expressing their liking: knowing the bunch of Kitui mango varieties with their range of qualities and flavours provided a baseline to judge the other samples accordingly. On the other hand, some KAPA participants have experienced mango flakes before, yet they still provided very high ratings, especially for the Kent variety. Hence, from an intrinsic standpoint, the variants produced during the STEP-UP project can be competitive in the local Kenyan market.

What could also be easily assumed is that the German market reference is a higher-quality mango variety. Yet, it must be highlighted that the main gap could be due to the processing carried out for the first time for Kikamba before additional training of the processing staff. The issue with sun drying is that the product can degrade if not done properly or in ventilated facilities. The first quality to be judged by a consumer when buying is generally the product's colour, which influences consumer acceptability. Hence, abnormal colour causes the product to be rejected by the consumer (Avila and Silva, 1999; Akoy et al., 2008). To maintain the dry mango's original colour without discolouration or darkening, a temperature of 80° is essential (being the optimal drying temperature). Still, the drying time also significantly affects the final output (Akoy et al., 2008). The gap between the colour (orange and shiny) of the German market reference and the Kenyan varieties might have affected the degree of enjoyment of other attributes (especially for the brown Kikamba). However, this is only speculation, especially considering that, although Kent was deemed as the variety with the best-looking colour by Kenyans, it was judged worse than Apple in terms of overall appreciation (yet slightly and not significantly). It must be noted that mango drying in Kenya is new. With ongoing practice of this value-addition strategy, the product's visual quality will likely increase with experience. Therefore, capacity building in training farmers and exporters remains imperative (even after the STEP-UP project) to meet the quality standards of the European Union (Ouedraogo and Chrysostome, 2019).

Considering the results from the MCT and related WTP analysis (where consumers shifted their preference choices in light of the explicated extrinsic attributes), the findings confirm the classical frameworks of consumer behaviour, which propose that food choices are the results of consideration of intrinsic (i.e., colour, texture, taste, etc.) and extrinsic factors (i.e., price, brand name, origin, packaging, organic and fair trade production), with the influence of the latter moderated by consumer demographic and socio-economic characteristics (Alphonce et al., 2015). Findings reveal differences in willingness to pay according to the respondents' profile and geography. In Germany, consumers with a higher awareness of fair-trade exhibit a higher mean for the expensive price point at which they would still buy the dried mangos compared to those with a middle to low awareness. In Kenya, the willingness to pay is much lower, even after knowing the extrinsic attributes, and the lack of finances is the main motivation underlying the willingness to pay. As consumers in Europe and other developed countries are becoming more critical in their food choices, the use of third-party certification has become very popular for credence attributes related to health, environmental benefits, fair trade, and animal welfare (Harper, 2001; Didier and Lucie, 2008; Rijswijk et al., 2008).

In this sense, the results suggest that, on the one hand, the organic and fair-trade labels are a good marketing strategy to apply for Germany. It should be considered, on the other hand, that most panellists were young and with a superior education. Highly educated consumers are more aware of health, show environmental concern, and benefit from greater purchasing power (Baiardi et al., 2012). Educated consumers seem to care more for organic products than the less educated (Smith et al., 2009). While educated European consumers are more prone to pay extra for organic products, most of the population pays more attention to locally produced products, even though they are produced with conventional methods. At the same time, they tend to discount imported products from developing countries even more than those from developed nations (this process is also known as a domestic bias for organic food) (Schjøll, 2014).

The country of origin indeed seems to be more important than the organic aspect of the product, with foreign origin (especially from developing countries) negatively affecting the willingness to pay (this also applies to developing countries importing foreign products) (Alphonce et al., 2015). This refers to labels such as organic, green, ecological, natural, and environmentally sustainable (where consumers often are unable to distinguish between these, associating all these terms to something that can be described as naturalness or greenness, which offer a counter for what conventional production is associated with: food poisoning, pesticides, antibiotics, hormones, etc.) (Aarset et al., 2004; Yiridoe et al., 2005; Olesen et al., 2010). This can also be due to the fact that some consumers do not see any added value from organic production or might associate some sanitary risk with it (Guilabert and Wood, 2012). On the other hand, while the country of origin can work as a depreciation factor for Europeans (especially within the elderly population), most case studies show that a certified fair trade label increases the willingness to pay a price premium (European Commission DGVI, 1997; De Pelsmacker et al., 2005; Didier and Lucie, 2008; Mahé, 2010; Cailleba and Casteran, 2011; Rotaris and Danielis, 2011). For example, in a 1997 Eurobarometer survey conducted in the European Union, 70 percent of the consumers were willing to pay at least a 10 percent premium for products with a fair-trade label (Alphonce et al., 2015). Indeed GAPA consumers with a high awareness of social fairness show overall higher means (especially for Apple, with 6.9 average scores point at the 9-point hedonic scale). This validates the hypothesis that the extrinsic attribute "fair trade" enhances the intrinsic attribute experience. This is not the case for Kenyans, though, where even people with a high awareness of fair trade and social working conditions did not display significantly higher means.

According to the study by Alphonce et al. (2015) on "European consumer preference for African dried fruits," 70% of consumers within the study sample prefer naturally produced products (i.e.,

dried fruits with no additives, sugar, or other preservatives) to products with more stable tastes. This corroborates the results of this study, which would suggest that an untreated Ngowe mango would be the best option for export, according to the KVTT results. The fact that it is free of additives must also be stressed and made as explicit as possible on the packaging. However, Lusk and Briggeman (2009) indicate that taste is a very important factor for consumer acceptance and cannot be neglected. In general, sensorial preferences for dried fruit are mainly driven by strong fruit aroma, sweetness, or acidic intensity (this explains why the Apple variant is the most appreciated among the Kenyan mango flakes in KAPA and GAPA) (Alphonce et al., 2015). The KVTT verifies this precondition. Contrarily, the lack of aroma, extreme hardness, and low sweetness combined with high acidity are sensory properties that consumers reject the most (Alphonce et al., 2015). Yet, people who prefer sweet flavours differ from those preferring strong, acidic, or sweet and sour flavours.

For this reason, according to KVTT results, Van Dyke with sodium metabisulfite, honey, or ascorbic acid treatments, together with Boribo treated with sodium metabisulfite or honey, are also strong candidates for export; a label with descriptive sensory attributes should be placed accordingly. This should go together with the fair-trade and organic labels, which are important because assessments of dried mango flakes in Germany show that meeting sustainability preferences through packaging and labelling could increase the willingness to pay by consumers with specific values and consumption behaviours.

According to KAPA results, while participants are highly open to the Kenyan mango samples from an intrinsic standpoint, the extrinsic attributes did not produce any effect on their degree of enjoyment or WTP with respect to Kenyan responders. The only statistically significant correlation in terms of consumption choices was between healthy and non-healthy product buyers regarding Kent colour and between natural product buyers and regular buyers concerning the overall impression of Kent. The willingness of Kenyan consumers to pay is significantly lower than that of German consumers. While this could be attributed to the higher cost of living and salaries in Germany, the willingness to pay is not correlated with the income of the respondents. The initial findings of our study are consistent with those of Mujuka et al. (2021), which indicate a low consumer awareness of the processed product. Additionally, Kenyan consumers here indicate a very low willingness to pay for dried mangoes between USD 0.7–0.9 per 100 g (Mujuka et al., 2021).

According to Ronteltap et al. (2007), in addition to the sensory attributes, consumer acceptance is determined by the costs and benefits. These include not just personal benefits, like usage and health-related benefits, but also societal benefits (in the case of dried mango, this would include local farmers' improved livelihood, reduced waste, and sustainable food production). Yet, the perceived benefit is not always equal to the actual benefit derived from innovation. Still, the personal considerations of such a cost/benefit analysis determine consumer acceptance from a traditional economic point of view. Thus, while the degree of acceptance related to the sensorial experience is high, the degree of acceptance from the traditional economic perspective is low (as a cost/benefit analysis, where a trade-off is made between societal benefits and economic costs associated with a certain technology or activity) (Ronteltap et al., 2007). This is because the average willingness to pay is set at less than 1 euro for a portion of dried mango, which is hardly sufficient to cover the marginal cost of production of high-quality mango flake varieties.

Thus, using non-endemic grafted varieties (comparatively more demanding regarding agricultural inputs) to process and produce mango flakes for the local market is less recommended due to its higher production costs. On the other hand, the people of Kitui have a long history of building food resilience through practices that make the most out of local agriculture and wild biodiversity. Kikamba mango fruit trees make an important contribution to fruit consumption, especially in drier areas where most fruit trees cannot survive during water stress, making mangos the most reliable source of fruits from December through April (Morimoto et al., 2010). Yet, a comparison with a countrywide database on traditional foods shows that less than 10% of traditional food species consumed by rural Kenyans go to Nairobi markets (Adeka et al., 2009). Considering the low initial costs and production costs of making Kikamba dried flakes and taking into account that most of these fruits spoil before reaching the market or being consumed, a large portion of the Kikamba harvest should be used to produce mango flakes (both for increasing shelf life and for guaranteeing easier access to local markets). Kikamba is a mango variety with a low water footprint and requires low inputs; thus, the dried mango produced from this variety has considerably lower production costs and will provide revenues that would be untapped if the fruit was purchased fresh (especially considering the high production losses that come from its production and delivery in fresh form).

While Kikamba is the least performing variety in terms of overall appreciation when untreated, when treated with honey, it produces higher degrees of appreciation than Apple and Kent (untreated) according to the KVTT. Considering the high degree of enjoyment generated by the two varieties and displayed in the KAPA results (even among people buying dried mango more frequently, suggesting that these varieties can be competitive in the local market), it is easy to predict that the Kikamba flakes treated with honey will represent a non-negligible source of revenue for local smallholder farmers.

To conclude, on the one hand, the valorisation of Kikamba, the local mango variety, is crucial. Still, on the other hand, an increase in the number of mango trees and varieties is required to guarantee a diversified and high-quality production (Ronner et al., 2019). This will resolve the high fruit perishability and transportability dilemma, potentially creating new businesses and a number of new mango products available to sell, thus opening many opportunities in the European market and providing a poverty alleviation strategy (Ronner et al., 2019).

This is a preliminary study collecting information of a general nature regarding the predisposition of Kenyan and German populations to dried mango from Kitui County. The research provides some inputs for a general interpretation of dried mango consumers' current values, habits, and predispositions. It is designed to establish a foundation upon which further and more in-depth research on markets and marketing strategies can be based. Extrinsic attributes impact the willingness to pay of both populations (since the sample is mostly young university students), yet the Kenyan population was affected to a lower degree. The Kenyan population shows a slightly higher predisposition for

natural products, while the German sample population did for fair-trade and organic (labelled) products. Accordingly, willingness to pay might be increased with fair-trade, organic, and sustainable labels for both populations. However, the degree of increment is uncertain due to the limited sample size and challenging settings of the taste testing. Further research and collaboration between academia and agricultural institutions are needed to identify the most appropriate and preferred mango varieties for producing mango flakes for export and local markets.

4.2. Study limitations

The first limitation of this study is that the sample is not representative of either Germany's or Kenya's populations. Although this research provides new insights for creating marketing strategies and processing optimisation to meet consumer preferences, the findings cannot be generalised at scale. Secondly, the factors determining consumer preferences should be explored in more detail using a variety of factors, including respondents' profiles, demographics, health status, personality, knowledge, exposure, and mood, as all of these can play a role in consumers' perception and evaluation of a particular product. Another study limitation relates to social desirability bias. Respondents may be concerned that researchers will judge their answers, thus misreporting their opinion. To avoid this issue, the study objectives and survey items were clearly explained to the respondents. Finally, the lack of experience with dried mangos among Kenyans respondents makes it difficult to assess whether high scores can be translated into a greater predisposition by Kenyans to enjoy local mango varieties or if other factors affect their preferences. Thus, as previously indicated, more research is needed to explore the determinants of mango consumers' preferences in Kenya.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the participants' legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

GU, JS, SL, MM, DM, and AC contributed to conception and design of the study. GU, JS, and SL organised the database and together with AC performed the statistical analysis. GU and AC wrote the first draft of the manuscript. GU, JS, SL, MM, and AC wrote sections of the manuscript. CM, LT, TM, DM, SS, and ER supported interpretation of data and together with all authors contributed to manuscript revision, read, and approved the submitted. All authors listed have made a substantial, direct and intellectual contribution to the work, and all approved it for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2023.1113930/full#supplementary-material

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EDITED BY
Željko Stević,
University of East Sarajevo, Bosnia and Herzegovina

REVIEWED BY
Adis Puška,
University of Bijeljina, Bosnia and Herzegovina
Ibrahim Badi,
Libyan Petroleum Institute (LPI), Libya

*CORRESPONDENCE
Godfrey Moses Owot
✉ gm.owot@gu.ac.ug

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Trust-supply chain performance relationships: unraveling the mediating role of transaction cost attributes in agribusiness SMEs

Godfrey Moses Owot[1,2]*, Daniel Micheal Okello[2], Kenneth Olido[3] and Walter Odongo[2]

[1]Department of Statistics and Economics, Faculty of Business and Development Studies, Gulu University, Gulu, Uganda, [2]Department of Rural Development and Agribusiness, Gulu University, Gulu, Uganda, [3]Department of Marketing and Entrepreneurship, Faculty of Business and Development Studies, Gulu University, Gulu, Uganda

The mediation effect of transaction cost attributes on the trust-supply chain performance relationships has remained largely under-explored. Particularly, little is known about the mediating role of information sharing, uncertainty and transaction frequency on the trust-supply chain performance relationships in the agri-food sector. Based on the transaction cost theory, this study used logistic regression to investigate the mediating role of transaction cost attributes on the trust-supply chain performance relationships. Data were collected from 396 agribusiness small and medium-sized enterprises, i.e., farmers (n = 203) and traders (n = 193) in Northern Uganda. Analysis was performed using logistic regression in SPSS version 23 and Amos version 23. The results show that, while trust positively influences supply chain performance, information sharing is the only transaction cost attribute that mediates the relationship between trust and supply chain performance. Agribusiness managers, therefore, need to not only renew the effort of sharing accurate and timely information regarding the market's demand for specific volumes and quality of agricultural products and market trends and storage facilities but also utilize the information to become competitive and improve supply chain performance.

KEYWORDS

transaction cost attributes, mediation, trust, supply chain performance, agribusiness relationships, Uganda

1. Introduction

The influence of transaction cost attributes on the trust-supply chain performance is becoming a topic of enduring interest in business relationships of industries (Akbar and Tracogna, 2018; Khan et al., 2018). The interest is sparked by a growing concern about its strong link to profitability and competitiveness (Radosavljevic, 2016; Puška et al., 2018). Transaction cost refers to the cost of information search and negotiation and implementation of contracts (Mbapila et al., 2019). It raises critical issues of opportunistic behaviors (Williamson, 2005), due to gaps in information sharing, level of uncertainty, and the frequency of transaction (Chang et al., 2012). Several scholars have looked at transaction cost attributes, trust and supply chain performance in agro-industries, and service companies in developed countries (Khan et al., 2018; Negi et al., 2018; Bremer and Lindqvist, 2019; Rashid et al., 2022).

Carraresi (2016) and Kabbiri et al. (2017) argued that transaction cost attributes in formal companies in developed countries are likely to reduce cost because of advancement in technology and ease of access to market information. These views were shared by Reardon and Barrett (2000) who contend that the honoring of contractual obligations in formal companies especially in developed countries, lowers cost. With no consensus on the constructs that constitute transaction cost attributes, Allen (1991) argued that the use of different constructs in different contexts brings out interesting results. Previous studies have largely considered relationships in agri-food companies with professional managers of those companies selected as respondents (Puška et al., 2022; Rashid et al., 2022; Gajdić et al., 2023). Management strategies in companies and for professionals are different from those of agribusiness SMEs with varying literacy (Zhao et al., 2020; Gera et al., 2022). Thus, this study is in a developing country's context and contributes in the following ways.

First, transaction cost and trust and supply chain performance have been explored extensively in the agri-food sector (Agustin et al., 2018). However, there is limited literature on its mediating role with regard to commodity chains and market typologies for individual firms in developing countries (Chang et al., 2012; Colquitt et al., 2012; Puška and Stojanović, 2022). The issue related to the type of quality of the fresh commodity is critical for its consumption. The consumption of fresh commodities is affected by culture which differs in developed and developing countries (Kyriacou and Rouphael, 2018). For instance, genotypic quality which covers functional quality aspects currently lacks a consistent regulatory context, especially in developing countries (Vergari et al., 2010). Furthermore, individual business partners in agribusiness relationships in developing countries face serious challenges in access to market information. In addition, violation of contractual obligations is rampant due to the weak legal system to address contract bridging (Owot et al., 2022).

Second, researchers have mainly combined and assessed the influence of information sharing and uncertainty on supply chain performance in non-agri-food supply chain. It is important to unearth the extent to which these constructs impact the relationship between trust and supply chain performance in the agri-food sector. Additionally, research is yet to take into account perceived transaction frequency and combine it with information sharing and uncertainties as a mediating variable in explaining the trust-supply chain performance. The inclusion of transaction frequency might provide new insights into the mediating role of these constructs. Previous studies in an online context have treated transaction frequency as a contingency factor and demonstrated that it moderates the main effect (Chang et al., 2012). Lately, no known studies in the food sector, especially in the fresh and dry commodity chain have considered this factor as a mediator in the trust-supply chain performance relationships in developing countries.

Third, although several studies have examined the mediating role of transaction cost attributes on the link between trust and supply chain performance as an outcome variable, a number of them have concentrated on business-based performance (financial and sales quota). Limited studies have assessed the relationships involving transaction cost, trust, and attitude-based performance (commitment and satisfaction). The assessment of attitude-based performance is an important aspect of relationship quality that provide benefits to supply chain members and improve competitiveness (Odongo et al., 2016).

Drawing from the preceding arguments, the general objective of this study is to explicate the mediating role of transaction cost attributes on the relationship between trust and supply chain performance. Specifically, this study analyzes the relationship between predictor (trust), mediator (transaction cost attributes), and outcome variable (supply chain performance), to check if they meet Baron and Kenny's (1986) conditions for the test of mediation.

The rest of this study is structured as follows. Section 2 discusses conceptual framework and hypothesis development where the literature review on transaction cost attributes relative to the mediating role of the trust-supply chain performance relationships and propositions is formulated. In Sections 3, 4, the methodology and findings from the agribusiness SMEs using questionnaires are presented and interpreted based on propositions. Finally, Sections 5, 6 conclude the study with a discussion of the implications as well as its limitations and direction for future research.

2. Conceptual framework and hypothesis

This study explores the mediation effect(s) of transaction cost on the trust-supply chain performance relationships by applying the transaction cost theory (TCT). The reasoning in this theory is that mutualistic profitable firms strive for closer relationships with business partners (Coase, 1937; Williamson and Ghani, 2012; Rindfleisch, 2020). It is suggested that a reduction in transaction cost enables firms to make profits in business relationships (Anderson and Gatignon, 1986). Williamson (2005) considers information sharing, uncertainty, and transaction frequency as market transaction cost attributes. Previous scholars have observed that it is important to make a choice of business partner based on the expectation of meeting lower costs from uncertainty and negotiating contracts (Anderson and Narus, 1990; Williamson and Ghani, 2012; Capaldo and Giannoccaro, 2015).

Accordingly, TCT treats transaction cost as a resource that provides mutual profits to supply chain members (Barney, 1991). According to Martins et al. (2010), exchange partners such as farmers and traders may not maximize profits if they do not pay attention to supply and demand information, market uncertainty, and the frequency of transactions. One, therefore, requires anticipation of what will happen in the market based on the information shared to enhance negotiations and outsourcing of products (Tisdell, 2004). Performance is determined by the costs incurred by the business partners in agri-business relationships (Nyaga et al., 2010). This study hypothesizes that transaction cost mediates the relationship between trust and supply chain performance to provide superior performance benefits to individual supply chain members as well as supply chain as a whole. Therefore, the application of this theory will help advance

a deeper understanding of the mediation effect of transaction cost on the supply chain performance of agribusiness actors of smallholder farming.

2.1. Supply chain performance

Supply chain performance is defined as the overall improvement in business operational measures of an individual and the whole supply chain as a result of opportunities created by trust (Odongo et al., 2016; Gera et al., 2022).

Trust is considered important for competitiveness in supplier–buyer relationships through a reduction in transaction cost (Mottaleb and Rahut, 2018; Mbapila et al., 2019). In agribusiness, transaction cost influences operational measures such as financial performance and sales quota. A change in financial security and cash flow from agribusiness defines the financial performance of business actors (Wahdan and Emam, 2017; Martins et al., 2019). Similarly, a change in the quantity of specific sales goal explain whether or not sales quota is achieved by supply chain actors (Good and Stone, 1991).

2.2. Trust and transaction cost

Transaction cost is defined as expenses incurred in market exchange. These are widely suggested to include the cost of discovering market prices, storage, and transportation (Dyer and Singh, 1998; Ali et al., 2017). In this study, transaction cost was measured by information sharing, uncertainty, and transaction frequency. Information sharing is defined as the extent to which production, storage, and market (demand and supply) information are regularly and accurately shared (Dyer and Chu, 2003; Ghosh and Fedorowicz, 2008). Information sharing is suggested to optimize the benefits of supply chain relationship when trust is built (Walker et al., 2018). Uncertainty is defined as unquantifiable technological risk arising from supply, demand, technology, and price that eventually impact the overall cost, quality, and cycle time (Khan et al., 2018; Gokarn and Kuthambalayan, 2019). According to Van Der Vorst (2000), uncertainty is the inability of business partners to predict accurately the impact of decisions on performance. Fynes et al. (2008) argue that uncertainties are eliminated by trust in a business relationship. Transaction frequency refers to a buyer's total purchase frequency from a specific seller in a business relationship within a particular time period (Chang et al., 2012; Zhao et al., 2020). Trust should influence the expectation of exchange partners in a business relationship to scale up transaction frequency (Chang et al., 2012). It is hypothesized that:

H_{1a}: Trust will be positively related to information sharing.

H_{1b}: Trust will be negatively related to uncertainty.

H_{1c}: Trust will be positively related to transaction frequency.

2.3. Transaction cost and supply chain performance

Transaction costs are regarded as the cost incurred on access to complete information about all the market conditions by buyers and suppliers, uncertainty, and transaction frequency (Fischer, 2013; Jraisat et al., 2013). This cost in a contractual arrangement is bounded by rationality (Simon, 1957). Transaction costs are minimized by taking different forms of information sharing, having joint problem solving, and safeguarding against opportunistic behaviors (Williamson, 1981; Walker et al., 2018). In the e-supply chain, transaction costs are mainly environmental and technological uncertainty (Puška et al., 2022). Transaction costs such as uncertainty and transaction frequency were found to influence buyer–seller relationships (Zhao et al., 2020). When critical information is shared timely and regularly, it enables supply chain members to become efficient in negotiation and subsequently increases business returns (Walker et al., 2018). Furthermore, information sharing plays a primary role in outsourcing, providing benefits of collaboration and alliances (Min et al., 2005; Gajdić et al., 2023). Information sharing has been suggested to have a positive influence on supply chain performance in previous studies (Baihaqi and Sohal, 2013; Odongo et al., 2016; Owot et al., 2022). This study hypothesized that:

H_{2a}: Information sharing has a positive effect on supply chain performance.

H_{2b}: Uncertainty has a negative effect on supply chain performance.

H_{2c}: Transaction frequency has a positive effect on supply chain performance.

2.4. Mediation effect of transaction cost

The influence of transaction cost on the relationship between trust and supply chain performance is well established in previous research (Odongo et al., 2016; Owot et al., 2022). Information sharing is viewed as a critical element for strengthening the achievement of common goals when trust is built by coordination and joint planning (Khan et al., 2018; Agarwal, 2019). Exchange partners who share complete information are considered to have an enabling environment for improvement in financial security by all exchange partners (Odongo et al., 2016). The existing literature has found information sharing a construct that lies in the heart of agribusiness relationship, influencing each exchange partner's trust toward one another (Khan et al., 2018), and supply chain performance in terms of competitiveness. Dominic and Theuvsen (2015) and Negi and Anand (2019) found that provision of market information by exchange partners brings confidence and trust and link them to markets with better outcomes of farmer-trader relations. Markets full of uncertainty create opportunism that eventually impacts the overall cost, quality, and cycle time (Khan et al., 2018; Gokarn and Kuthambalayan, 2019). Exchange partners who experience uncertainty tend to mistrust and predict inaccurately the impacts of decision on performance (Van Der Vorst, 2000; Fynes et al., 2008). No known study has assessed the mediating influence of transaction frequency on

buyer–supplier relationships. Against this background, this study hypothesizes that:

H_{3a}: Information sharing positively mediates the trust-supply chain relationships.

H_{3b}: Uncertainty negatively mediates the trust-supply chain relationships.

H_{3c}: Transaction frequency positively mediates the trust-supply chain relationships.

3. Methodology

3.1. Study context

Study respondents consist of literate, semi-literate, and illiterate farmers and traders dealing in tomatoe and soybean agribusiness. They were drawn from Lango and Acholi sub regions in Northern Uganda within the districts of Oyam, Kole, Gulu, Nwoya, and Omoro. Whereas, the selection of the two crops followed from the group of high-value crops (fresh and dry), contributing to income and livelihood through commercialization (Owot et al., 2022), the selection of the two regions was based on the fact that one of the districts from each of this region was elevated to city status in 2018. The emergence of the two cities has created a new level of aggregate demand for fresh and dry commodities.

3.2. Data collection

In this cross-sectional survey study, data were collected between September and November 2019 from farmers and traders using a structured questionnaire. Approximately 400 respondents were contacted to participate in the interviews. However, there were four respondents who chose not to complete the interviews on business emergencies. Hence, 396 questionnaires from 203 farmers and 193 traders were fully filled and qualified for analysis (Table 1).

Sampling began with identifying districts and sub-counties in which the respondents were located using two-stage sampling procedures, where in the first stage, five districts were selected, and in the second stage, 15 sub-counties got identified. After identifying the respondents' location, a purposive sampling technique was used to identify farmers participating in agribusiness in the two crops, specifically those who nominated the traders. Snowballing was used to follow and interview the nominated traders in the sub-counties, identified on the same questions given to farmers. The farmers and traders were selected based on their age (at least 18 years old), business age of at least 1 year of business relationships in soybean and tomatoe agribusinesses, and should have been engaged in an informal or contractual agribusiness relationship. These respondents constituted both the unit of inquiry and the unit of analysis. Farmers who met the inclusion criteria were purposively identified and asked to nominate traders with whom they are in a business relationship in a snowball sampling approach.

Roscoe (1975) suggests that for a study of an unknown population, the sample sizes have to be more than 300 and <500, applications for an utmost research, and it is believed to be appropriate for most behavioral research. Therefore, using Roscoe's rule of thumb, at a 5% level of significance, a sample of 203 farmers and 193 traders was selected to minimize sampling error and obtain statistical convergence. Table 1 indicates the category of respondents, and the sampling techniques used based on their relevance.

TABLE 1 Sample size determination.

Respondent categories	Type	Population	Sample size	Sampling techniques
Farmers	Individual farmer	Unknown	203	Purposive
Traders	Market trader	Unknown	193	Snowballing
Total		Unknown	396	

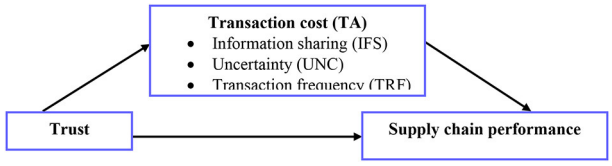

FIGURE 1
Conceptual framework. Source: Adapted and modified from Hayes (2009).

TABLE 2 Sample characteristics of respondents ($N = 396$).

Variable		Frequency	Percentage (%)
Gender	Male	244	61.6
	Female	152	38.4
Business partners	Farmers	203	51.3
	Traders	193	48.7
Age	<26 years	51	12.8
	26–35 years	152	38.4
	36–45 years	90	22.7
	46–55 years	65	16.4
	Over 55 years	38	9.7
Education status	Literate	43	10.9
	Semi-literate	170	42.9
	Illiterate	183	46.2
Years in Business	5 years or less	125	31.6
	6–10 years	159	40.2
	11–15 years	69	17.4
	More than 15 years	43	10.9

3.3. Measurement scaling

The variables in this study were operationalized. Transaction cost attributes were conceptualized based on the dimensions of

information sharing, transaction frequency, and uncertainty as adopted from previous scholars (Chang et al., 2012; Khan et al., 2018). To describe information sharing, eight items were selected. For uncertainty, eight items were chosen to capture the construct. Concerning transaction frequency, this construct was represented by six selected items. In addition, trust was conceptualized as benevolence, integrity, and competence (Sekhon et al., 2014; Xue et al., 2018; Franklin and Marshall, 2019). Seven, six, and four items were selected to measure benevolence, integrity, and competence, respectively. The dimensions of financial performance, sales quota, commitment, and satisfaction were adapted to measure supply chain performance (Bunte, 2006; Fearne et al., 2012; Chou and Chen, 2018; Qian et al., 2020). Therefore, in this study, the measures developed and used by scholars above were adapted to measure constructs of the outcome variables. Five, four, and seven items were selected to measure financial performance, sales quota, commitment, and satisfaction, respectively. Measurements of all items were anchored onto a five-point Likert scale starting from strongly agree (5), agree (4), not sure (3), and disagree (2) to strongly disagree (1).

3.4. Reliability and validity of constructs

The results of composite reliability of the constructs provided by Cronbach's alpha meet the minimum threshold for adequate reliability (Fornell and Larcker, 1981). Furthermore, the study conducted a confirmatory factor analysis to determine the validity of the latent constructs. Accordingly, the measurement model provided a reasonably good fit ($\chi^2 = 32.996$, degrees of freedom = 24 and probability level = 0.104; CFI = 0.992; TLI = 0.989; IFI = 0.992; and RMSEA = 0.031) (see Figure 1). In addition, the study constructs met conditions recommended by Gerbing and Anderson (1988) that all factor loadings should be >0.50 for convergent validity. Discriminant validity was assessed through a comparison of variance between the constructs and average variance extracted (AVE) for each individual construct (Fornell and Larcker, 1981). The conditions for discriminant validity recommended by Gerbing and Anderson (1988), for the diagonal elements, representing the square roots of the AVE for each construct to be greater than each of the off-diagonal elements in the rows and columns corresponding to it were met. The results demonstrate sufficient discriminant validity between factors.

3.5. Descriptive analysis and parametric assumptions

Data were analyzed in SPSS version 23. Upon collection, data were captured in SPSS for preliminary analysis. These included missing data screening and checking for outliers, normality, multicollinearity, and homogeneity parametric assumptions. Frequencies run did not show that missing values were a problem. In addition, the box plots did not reveal the existence of outliers. Concerning the normality of data, the histogram was bell-shaped, and most observations on the P-P plots fell along a straight line. Multicollinearity was tested using the variance inflation factor (VIF) and tolerance level, which provided values within acceptable limits (VIF < 4 and tolerance > 0.2) to conclude that multicollinearity was not a problem. Homogeneity parametric assumptions were checked using Levante's test (Field, 2005). The results revealed that Levante's test for all variables was not significant at $P > 0.05$, which indicates that variances were stable at all levels. Hair et al. (2013) argued that the presence of both outliers and missing data may affect multivariate analysis when poorly managed. With most of the preconditions for multivariate analysis met, the key hypothesis of mediation was tested using bootstrapping structural equation modeling in Amos based on Baron and Kenny (1986) and Rashid et al. (2022).

4. Results

4.1. Population characteristics

The results in Table 2 revealed that 62% of the farmers and traders were male while 38% were female. Of these respondents, 51% were farmers while approximately 49% were traders. Furthermore, the results also showed that the majority (38.4%) of the respondents were in the 26–35 age range, while 22.7% were in the 36–45 age range. On the aspect of education status, the findings revealed that 46.2% were illiterate and 42.9% were semi-literate. Moreover, the results indicated that 40.2% of the respondents were in agribusiness for a period of 6–10 years, followed by those who were in business for 5 years or less at 31.6%.

4.2. Relationship between trust and transaction cost

To model the relationship between trust and transaction cost, a regression model was run to determine the influence on each transaction cost attribute (information sharing, uncertainty, and transaction frequency). Table 3 presents that the path from trust to information sharing was positive and statistically significant (b = 0.57, S.E = 0.04, $P \leq 0.001$), providing support for H_{1a}.

4.3. Effect of transaction cost on supply chain performance

The effects of information sharing, transaction frequency, and uncertainty on supply chain performance were found to be positive for the first two constructs and negative, respectively (see Table 4). The influence of information sharing (b = 0.7284, S.E = 0.1440, $p < 0.01$), uncertainty ($b = -0.3741$, S.E = 0.3028, $p < 0.1$), and transaction frequency (b = 0.3741, S.E = 0.1855, $p < 0.05$) on supply chain performance (SCP) was significant. Thus, hypotheses H_{2a}, H_{2b}, and H_{2c} were supported.

TABLE 3 Relationship between trust and transaction cost.

H	Variables	Coefficient	S. E	*R*	*t*	*P*	Level
H_{1a}	Trust vs. information sharing	0.57	0.04	0.63	155.81	0.00	Sig
H_{1b}	Trust vs. uncertainty	−0.04	0.02	0.81	−1.59	0.11	Not sig
H_{1c}	Trust vs. transaction frequency	0.05	0.04	0.07	1.44	0.15	Sig

$N = 396$, $p < 0.01$; Not.sig, Not significant; Sig, Significant.

TABLE 4 Effect of information sharing, uncertainty, and transaction frequency on SCP.

H	Model	Coefficient	S. E	Z	P	LLCI	ULCI	Level
	Constant	−3.13	1.28	−2.45	0.01	−5.64	−0.62	
	Trust	0.76	0.14	5.32	0.00	0.48	1.05	
H_{2a}	IFS	0.72	0.16	4.57	0.00	0.42	1.04	Sig
H_{2b}	UNC	−0.58	0.30	−1.92	0.06	−1.17	0.01	Sig
H_{2c}	TRF	0.37	0.19	2.02	0.04	0.01	0.74	Sig

$N = 396$, $p < 0.01$, McFadden < 0.5, CoxSnell < 0.5, Nagekrk < 0.5; Sig, Significant.

4.4. Mediating effects of transaction cost attributes

To understand the mediation effects of transaction cost attributes, i.e., information sharing, uncertainty, and transaction frequency on the trust-supply chain performance relationships, the test of mediation was performed using non-parametric bootstrapping. The results show that only information sharing (0.26, 0.64) mediated the relationship between trust and supply chain performance (SCP). This provides support for hypothesis H_{3a} (see Table 5).

5. Discussion

The general agreement in supply chain management is that transaction cost attributes in formal companies in developed countries lower cost and improve competitiveness. Sparked by a growing concern about the low level of income and livelihood of smallholder farmers in developing countries, the need to engage in business relationships with better performance outcomes is becoming critical. This study investigated the mediating role of transaction cost attributes on the relationship between trust and supply chain performance. This study found that trust increases supply chain performance and information sharing and information sharing and transaction frequency increase supply chain performance. Furthermore, uncertainty reduces supply chain performance. As far as mediation is concerned, information sharing mediates the relationship between trust and supply chain performance.

The results from the multiple regression model show that trust increases information sharing. This is in agreement with previous studies (Odongo et al., 2016; Franklin and Oehmke, 2019; Na et al., 2019). This suggests that by increasing the ability of sharing useful information among farmers and traders, trust is built, and supply chain members become more transparent and accountable to each other. This view was shared by Khan et al. (2018), who pointed out that trust is built easily with honesty in sharing of information regarding market price and the taking of actions that reduces costs. Accordingly, whereas past studies provided empirical support for supply chain performance in developed countries in a non-agri-food context, this study extends this to agri-food small and medium enterprises in agribusiness relationships in developing country's context.

Regarding mediation effects, farmers and traders perceived information sharing to increase the influence of trust on trust-supply chain performance relationships. This finding is consistent with previous studies (Alaarj et al., 2016; Walker et al., 2018), which reported mediation of information sharing on trust-supply chain performance relationships. This suggests that trust simply sets a foundation for superior supply chain performance, while it is through information sharing that the value of trust is fully realized in the supply chain performance of supply chain actors. This suggests that failure to timely and accurately share market information may bring problems. The absence of information sharing may make supply chain members become unwilling to trust business partners on issues related to investment and market decisions. Consequently, they may seek market information from outside the relationships (other farmers, middlemen, or processors), which weakens the relationships and reduces competitiveness. Information sharing is important for lowering the cost of information search, understanding expectations, increasing the rate of innovations, and enhancing the competence of business partners. In Uganda's context, market information is for linking farmers to markets with better prices with good profit margins. Consequently, agribusiness SMEs would prefer to engage in business relationships with a higher likelihood of access to market information by the chain members, hence better income and supply chain performance.

6. Conclusion

In the context of agribusiness supply chains in developing countries, this study links trust with supply chain performance, providing the mediation effect of information sharing among

TABLE 5 The mediation effect of transaction cost attributes.

H		Effect	BootSE	BootLLCI	BootULCI	Level
	Total	0.46	0.10	0.29	0.69	
H_{3a}	IFS	0.42	0.09	0.26	0.63	Sig
H_{3b}	UNC	0.02	0.02	−0.01	0.08	Not sig
H_{3c}	TRF	0.02	0.02	−0.01	0.06	Not sig

Direct effect effect = 0.77, S.E = 0.14, $p < 0.01$, $Z = 5.32$; Not sig, Not significant; Sig, significant.

farmers and traders. The results revealed that trust among farmers and traders has a positive relationship with supply chain performance and information sharing when entered into the trust- supply chain performance relationships played an important role in mediating the relationships. The practical implication of these findings is that sharing accurate and timely information among farmers and traders who have trust would improve the supply chain performance of chain members than simply building trust.

The literature suggests the mediating role of all transaction cost attributes (transaction frequency, uncertainty, and information sharing), seen in all formal organizations in the context of the service sector or manufacturing industry. However, the emergence from the data that there is only one attribute (information sharing) with a significant mediation effect implies that its mediating role could vary by the level of formality in the relationships and trust dimensions. The literature suggests that information sharing mediating the trust-supply chain relationship may be questioned in the context of a formal company when trust is understood from its dimensions in agri-food relationship. The study highlights the practical difficulties in using the mediating influence of information sharing in giving superior performance when trust is a block concept. Therefore, the analysis of the mediating role of information sharing should consider breaking trust into integrity, benevolence, and competence. Future studies may generate more detailed information when the mediating role of information sharing on SCP among SMEs is considered in formal organizations. Most agribusiness SMEs interviewed were in less formal agribusiness relationship, and perception could vary based on the status of registration and the level of formality involved in agribusiness relationships. This study proposes that future research could replicate this design in a formal organization but using dimensions of trust to understand more insights into the mediating role of information sharing.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Gulu University Research and Ethics Committee (GUREC). The patients/participants provided their written informed consent to participate in this study.

Author contributions

GO collected the data and statistically analyzed it and wrote the manuscript. GO and DO interpreted the content of the output. WO and KO were instrumental in reading and approving the final manuscript. All authors participated in the formulation of overarching research aims and objectives, including the responsibility for management and coordination of the research activity planning and execution. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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EDITED BY
Wolfgang Bokelmann,
Retired, Berlin, Germany

REVIEWED BY
Thomas Aenis,
Humboldt University of Berlin, Germany
Fabio Pachón,
Universidad Nacional de Colombia, Colombia

*CORRESPONDENCE
Klaus Droppelmann
✉ klaus.droppelmann@picoteam.org

†These authors have contributed equally to this work

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Making the sustainability hotspot analysis more participatory—experiences from field research in Zambia

Klaus Droppelmann[1*†] and Carolin Müller[2†]

[1]Picoteam Ltd., Johannesburg, South Africa, [2]Independent Scholar, Berlin, Germany

Food value chains constitute a core element of food systems. Along any value chain, several bottlenecks, and obstacles negatively affect the sustainability of the entire chain. Therefore, the identification and assessment of such sustainability hotspots is a vital step in the process towards higher levels of sustainability. Over the past few decades food value chains have been supported as part of development cooperation to help alleviate poverty and ensure food and nutrition security. However, so far, a suitable methodology to assess aspects of sustainability along such food value chains was not available. Therefore, we have adapted the sustainability hotspot analysis, originally developed by the Wuppertal Institute, and enhanced it with a participatory approach, thereby making it suitable for application in the context of development cooperation. In this paper, we present a step-by-step overview of the entire assessment process by using examples from its application in Zambia's dairy and groundnut value chains. The developed methodology allows, through participatory means, the identification and assessment of sustainability aspects by stakeholders themselves, with the validation and amplification of assessment results by locally-based value chain experts. We demonstrate that results from this participatory hotspot analysis are aligned with the principles of agroecology promoted by the FAO, and are geared towards supporting transformative food system change processes. Our key findings from the application of the participatory hotspot analysis showed that sustainability hotspots occur in the social, economic, and ecological dimensions of sustainability along both value chains. It also became clear that hotspots are frequently interconnected, requiring a holistic approach based on a solid understanding of strong sustainability when designing solutions. We conclude that our participatory hotspot analysis provides a user-friendly methodology that generates action-oriented recommendations, and provides an ideal starting point in the development process for co-learning and co-creation of knowledge aimed at generating sustainability-enhancing innovations. The application of the participatory hotspot analysis reveals information on aspects that threaten the sustainability of value chains from a stakeholder perspective. Knowledge of these perspectives is essential, especially for development practitioners tasked with designing implementation strategies to improve the sustainability of value chains.

KEYWORDS

food value chains, sustainability, hotspot analysis, smallholder agriculture, participatory, knowledge co-creation

1. Introduction and objectives

Poverty reduction and food security remain high on the agenda of international development cooperation. To date, value chain (VC) development has been one of the most widely used tools to achieve these development goals. Despite this, in recent years, the number of people suffering from hunger or malnutrition has been increasing once again. At the same time, the number of people affected by obesity, diabetes, or other noncommunicable diseases is also increasing (WHO, 2022). The reasons for this are manifold and complex. However, one thing is clear—our current food systems are already failing us. This is evident not only from current trends in poverty, hunger, and malnutrition, but is also underlined by the alarming trends of soil degradation and the loss of biodiversity due to more and more land clearing for agricultural activities, that go far beyond planetary boundaries. Social distress and economic insecurity are alarming consequences of these developments (Allen and Prosperi, 2016; Ruerd et al., 2021). Therefore, a shift towards a system that allows for the availability and accessibility of healthy food to meet current food needs is required. This must occur while respecting planetary boundaries to help maintain healthy ecosystems and provide food and ecosystem services for future generations (Allen and Prosperi, 2016). In a food system, food production plays a central role. However, the importance of what Ruerd et al. (2021) refer to as the 'food environment' should not be overlooked: "The food environment incorporates all the infrastructure, public and private, institutional regimes and governance frameworks that guide food availability, accessibility, quality, safety, sustainability, reliability, and affordability. There are structural imbalances and disconnects that prevent the delivery of desired outcomes for nutrition, inclusion, and environmental sustainability." Therefore, it is important to acknowledge that food value chains (VCs) constitute the core element of food systems and are themselves complex systems.

To date, little attempt has been made to connect food VCs to the systemic and multi-dimensional understanding of sustainability. Existing instruments for sustainability assessment along VCs either completely disregard the multi-dimensional nature of sustainability, or are too complex and time-consuming to be broadly used by practitioners. Consequently, a suitable methodology is lacking to assess sustainability issues along food VCs in a holistic fashion. Furthermore, definitions of sustainability are mostly pre-defined by academia, and not based on the understanding and realities of the people engaged in the promoted VCs. Oftentimes, the lack of involvement of the target groups is one of the reasons why development projects, especially VC support interventions, are not successful in achieving their desired outcomes (Stoian et al., 2012). Our objective was to design a robust, scientifically based methodology that employs a participatory approach to assess sustainability aspects along food VCs. The assessment results aim to inform management decisions in food VC governance to enhance the multi-dimensional sustainability of the VC, and contribute to the transformation of the entire food system it is embedded in. This paper will introduce a newly designed participatory HotSpot Analysis (pHSA), as a combination of the Wuppertal Institute HotSpot Analysis (WU-HSA) (Bienge et al., 2009), and the adaptive MAnagement of vulnerability and RISk at COnservation sites (MARISCO) methodologies (Ibisch and Hobson, 2014).

2. Existing sustainability assessment and participatory approaches

Based on a literature review we identified the hotspot analysis developed by the Wuppertal Institute of Climate, Environment and Energy (WU-HSA) as a suitable starting point for the design of a new sustainability assessment methodology. In order to take the living situation of smallholder farmers in a development context into consideration we decided to introduce participatory elements which we adapted from the MARISCO methodology.

2.1. The Wuppertal hotspot analysis

The WU-HSA aims to identify priority areas for interventions relating to sustainability (i.e., sustainability hotspots) along food VCs (Bienge et al., 2009; Liedtke et al., 2010; Rohn et al., 2014). Briefly put, the WU-HSA assessment is carried out over three steps. In the first step, the VC in question is separated into distinct phases, e.g., production, aggregation, processing, retailing, and consumption. In the next step, external and internal VC experts are invited to assess the relevance, or criticality, of each of these VC phases in relation to the sustainability of the entire chain by assigning values from 1 (low) to 3 (high). In the final step, sustainability aspects in each of these phases are identified, evaluated, and again assigned a value of 1 (low) if this aspect does not indicate a sustainability failure, to 3 (high) if it threatens the sustainability of the entire VC. On completion, the two values are multiplied. If the product for a specific sustainability aspect within a specific VC phase is 6 or larger (up to 9), this aspect is considered a sustainability hotspot. Bienge et al. (2009) provided an example of this calculation: if the social aspect 'general working conditions' were to be assigned a relevance of 3 in the production phase, and a relevance of 2 in the processing phase, while the VC phase 'production' is assigned a relevance of 3, but 'processing' only 1, then the aspect 'general working conditions' becomes a hotspot in production ($3 \times 3 = 9$), but not in processing ($2 \times 1 = 2$). While the WU-HSA takes a multi-dimensional and holistic approach, it has not been adapted to be applied in a development context, where the prime target population of support interventions is usually a large group of resource-constrained, smallholder farmers in a rural setting. Moreover, the WU-HSA relies mostly on expertise from academics, external experts (i.e., not directly involved in the VC), and managers and operators from downstream stages of the VCs in question. Although the procedure is straightforward, quick, and easy to implement, we found it lacking in two respects: the level of detail of the analysis, and the lack of participation of the primary target group in the analysis.

2.2. The MARISCO approach

To add a strong participatory element suitable to engage with smallholder producers, we adapted specific elements of the MARISCO methodology (Ibisch and Hobson, 2014). MARISCO was developed to support management decisions on risks and vulnerabilities experienced by communities living in and around conservation sites, such as national parks and reserves. The MARISCO methodology takes a holistic and systemic livelihood-based approach to the

planning process. We adapted its livelihood-centered approach and simplified the evaluation process to suit the requirements for sustainability hotspot assessments in a development context. The specific elements are (1) the listing of resources (MARISCO uses the term attributes) necessary for a successful participation in the dairy and groundnut value chains, (2) the steps to identify services and systems that provide or maintain these resources and their related sustainability aspects (for an illustration also see Figure 1 below), and (3) the process to assess the functionality of these systems by identifying and evaluating threats to these sustainability aspects.

3. Designing the participatory HotSpot analysis

The pHSA takes a multidimensional approach to assessing VCs encompassing economic, social and ecological aspects of sustainability. This holistic approach is targeted towards identifying high-priority areas throughout all phases of the VC, by evaluating aspects that go beyond the economic dimension of sustainability. In general terms, and following Bienge et al. (2009), we refer to such high-priority areas as sustainability hotspots. In the specific context of our study, sustainability aspects are evaluated using a set of criteria to arrive at a numerical value. Above a certain threshold we assume the sustainability of a specific aspect threatened, which is then defined as a sustainability hotspot. Thus, the results of the hotspot analysis help identify action points that will result in the highest impact. This is achieved by taking the livelihood of small-scale farmers engaged in food VCs as a point of departure, and integrating their understanding of sustainability and their value perceptions into the analysis. Due to its participatory nature the pHSA may offer the additional benefit to initiate processes of knowledge co-creation and co-learning in order to enable the discovery of innovations necessary to address identified sustainability hotspots. This paper presents the steps taken to develop the pHSA and provides examples of its implementation on the ground. The method has been applied in a pilot trial in the groundnut and dairy VCs in Zambia. To ensure, as much as possible, the broad applicability of the pHSA an animal-based and a plant-based food value chain were chosen.

3.1. The pHSA methodological approach—step-by-step

3.1.1. Preparatory phase—literature review

To prepare for the sustainability assessment it is useful to familiarize oneself with the entire VC to be investigated and the concept of agroecological principles and transformative food system change. This may include scientific literature as well as grey literature, like project reports, newsletters etc. Detailed knowledge about the VCs is critical to establish the context of the study and may later on feed into the science-based verification of results. If further adaption to pHSA methodology appears necessary, it is helpful to gain a basic understanding of the WU-HSA and MARISCO methodologies.

Our preparatory phase included the conceptual development of the pHSA methodology based on intensive literature reviews of the WU-HSA and MARISCO methodologies, as well as literature on AEPs and the specific VCs we intended to analyze in our study. We collected as much information as possible on critical sustainability aspects of the VC from both a global and country perspective. Information about stakeholder groupings along the VC stages, and the identification of the target population for the study, was also crucial to ensure all analysis results will be relevant, representative, and transferable beyond the actual scope of data collection. For example, in a development context, the target group may be limited to participants of VC support programs, as was the case for us, while the objective of a purely research-oriented project might be to draw more generalized conclusions for an entire sector or a country level. The latter requiring a larger sample size that allows for statistical analysis.

3.1.2. The pHSA for the production phase

To capture the different living realities within a smallholder community, the study participants should be disaggregated by gender and age. Thus, focus groups may be formed of senior women, senior men, and male and female youths—each of 4–6 members per sub-group. At the start of the focus group discussions (FDGs), participants should be asked to identify the basic resources they need to engage and maintain their successful participation in the VC. Employing 'free-listing' (Quinlan, 2018), all resources are collected, documented on moderation cards, and then placed in a

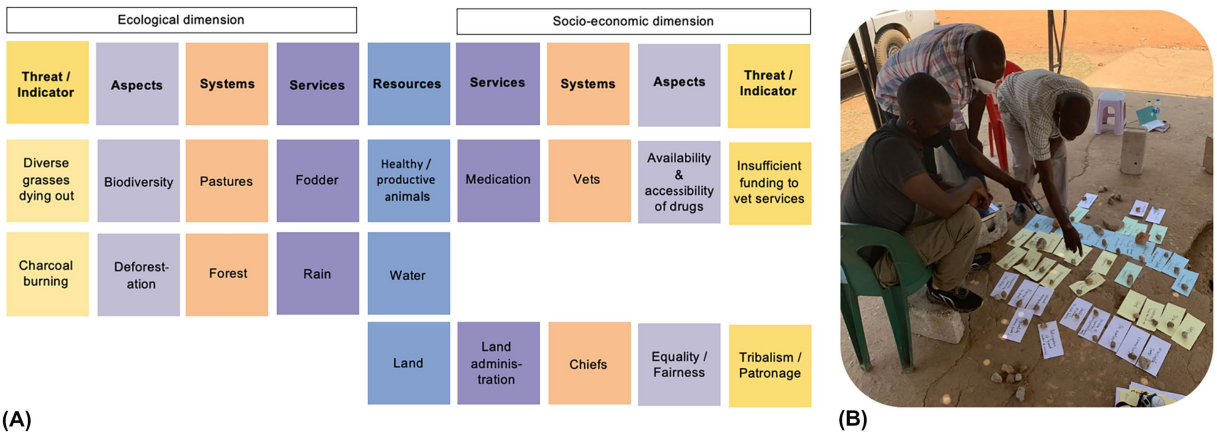

FIGURE 1
Stylized example of an pHSA sustainability assessment matrix **(A)** and an actual example from a FGD in Monze **(B)**.

vertical row on the ground. In the subsequent steps, the socio-economic and ecological services participants need to access to obtain these resources are identified. In our study, for example, a key resource for a viable dairy enterprise was "healthy and productive dairy animals." To maintain their productivity and health, the dairy farmer has to be able to provide them with quality fodder. Again, the terms or phrases describing such services are written on moderation cards and related to the basic resources row by row. Socio-economic services are arranged to the right of the corresponding resource cards and ecological ones to the left. Participants are then asked to identify systems that provide these services. In our example, productive pastures or rangelands would provide fodder for livestock. Cards, labeled accordingly, will again be placed next to the corresponding service cards. Participants are then asked to identify sustainability aspects that impact those systems—for example, the aspect "biodiversity of grass species" impacts the long-term productivity of rangelands. The aspects are written on moderation cards and placed next to the corresponding systems. In the next step, the participants are asked to identify threats. As threats have a negative impact on these sustainability aspects, we prefer this term rather than the term 'indicator', as used by the Wuppertal Institute. For example, the loss of certain grass species may threaten the sustainable functioning and productivity of rangelands. The threats are discussed and agreed upon by the participants and then documented on evaluation cards, together with the corresponding sustainability aspects. Figure 1 shows a stylized example of an assessment matrix, as well as a picture from an FGD in Monze.

The evaluation of these threats follows a more detailed protocol compared to the WU-HSA approach. We use four criteria to assess individual threats: scope, severity, permanence, and trend. Each of these criteria is evaluated by the FGD participants using the scale: 1 (low), 2 (medium), and 3 (high). As facilitators, it is helpful to note how participants define the criteria levels, thereby allowing a better understanding of their reasoning. To establish the impact of a threat, the values assigned to the first three criteria are added up: (1) scope (i.e., how widespread is this threat?); (b) severity (i.e., how damaging is this threat?); and (c) permanence (i.e., how easily can this threat be addressed?). Adding values for the current trend of this threat—decreasing (1), stable (2), or increasing (3)—provides a measure of the significance of the threat to the sustainability aspect. A significance value of 10 or higher indicates a sustainability hotspot that requires immediate attention. Figure 2 shows an example of an evaluation card that has been filled in. Resources permitting, minor threats to sustainability with significance values of 9 and lower would still be worthwhile addressing at some point. Additional data collection applying participatory research methods is recommended to provide more context for analyzing the hotspot evaluation results. Especially if, along with the hotspot identification and evaluation, potential innovations and underlying trade-offs are to be researched. Figure 2 shows an example of a pHSA evaluation card on the left, and an actual example of the evaluation process during an FGD in Monze district.

3.1.3. Additional, optional field data collection

To complement the data collection from the FGDs, we suggest collecting information using participatory research methodologies, including transect walks, seasonal calendars, and Venn diagrams. The objective of this additional data collection is to gain a deeper and more comprehensive understanding of the smallholder farmers' livelihood situation and work environment. This data collection can run parallel to the FGDs, and ideally involves both male and female community leaders and lead farmers. In our case, these exercises proved valuable in identifying and discussing conflicts over resources in the community, potential innovations, and successful or failed communal action projects. These exercises usually took 1.5 to 2 h. Notes were transcribed as soon as possible for later analysis. These additional participatory exercises are not vitally important for assessing sustainability aspects. However, they might be extremely valuable for detailed investigation of innovations developed by pioneering individuals or communities, as well as the in-depth identification of needs for further innovations.

3.1.4. The pHSA for downstream VC phases

VC interventions in a development context aim to ensure the fair and just distribution of value addition, thus contributing to the improvement of smallholder livelihoods. Hence, the pHSA is biased towards the production phase. However, to gain a comprehensive understanding of an entire VC, stakeholders from downstream phases must also be included in the evaluation. Typically, these stakeholders will be individual representatives of companies and organizations active in the input, aggregation, transport, processing, and retailing phases. Consequently, we prepared semi-structured interview guidelines customized to each VC phase. As a first step in the key informant interviews (KII), following the introduction, we presented available preliminary findings from the FGD and other KII. Then

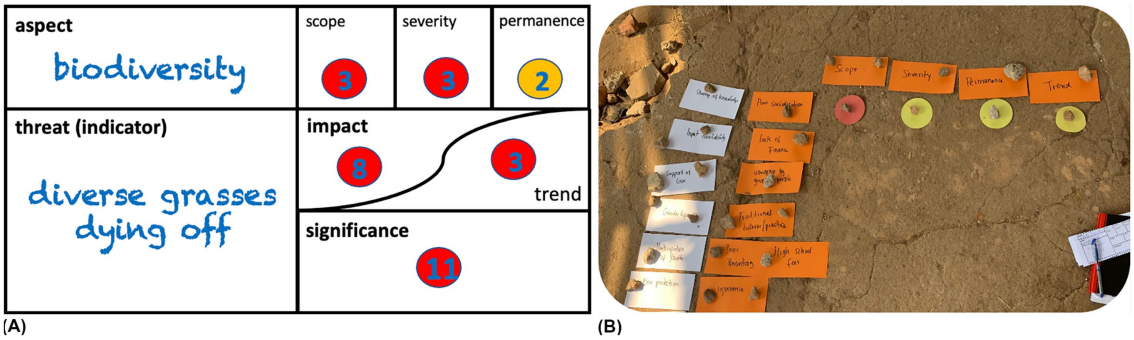

FIGURE 2
Example of a pHSA evaluation card **(A)** and an actual example of the evaluation process during a FGD in Monze **(B)**.

we invited the key informants to provide feedback and verify the identified hotspots. Following that, we asked them to identify additional hotspots along the VC, and evaluate them using the evaluation procedure described above. They were also encouraged to share any observations on potential innovations and trade-offs. Generally, these interviews lasted between 1 and 1.5 h.

3.1.5. The pHSA approach to validate preliminary results

After data entry and cleaning, preliminary findings and observations can be generated and presented to a select group of locally based experts for validation. We organized a validation workshop, with attendees mainly recruited from VC-supporting and -enabling agencies [see Springer-Heinze (2018) for definition and details], along with some VC operators based in Lusaka. Such a group of stakeholders is particularly well suited to provide an impartial perspective on the challenges of the entire VC and its contribution to the whole food system. As with the key informant interviews, our preliminary findings from both VCs were presented and put up for discussion. To handle the large amount of information, and to collect the feedback from the participants in an efficient manner on the identified hotspots, we used Mentimeter[1]. Following this exercise, participants discussed and identified innovations and trade-offs along the VCs in smaller working groups. At the end of the workshop, rapporteurs from the individual working groups presented the results of their discussions to the plenary. This validation of our preliminary data ensured the appropriateness, robustness, and comprehensiveness of our field data collection.

3.2. Equipment and resources needed for applying the pHSA

The pHSA is a qualitative research methodology for which no special materials or equipment are necessary. For the facilitation of focus group discussions and validation workshops, standard participatory rural appraisal (PRA) materials will be needed, e.g., markers and cards for moderation and evaluation. Flip chart stands and pin boards might be useful but are not essential. For the documentation of additional PRA exercises (e.g., Venn diagrams, seasonal calendars, and/or transect walks), PRA handbooks provide good guidance. To document key informant/expert interviews, we used paper notebooks and semi-structured interview guidelines. Consent, whether in written or oral form, from all participants needs to be obtained in order for them to participate in the research study. In our opinion, the use of recording devices and their subsequent analysis is not necessary, since preliminary summaries or conclusions should be generated by the participants themselves and agreed with them before documentation. To capture results from the focus group discussions (i.e., evaluation cards), we used simple data spreadsheets (e.g., Microsoft Excel). In these spreadsheets, the responses were coded using a combination of deductive and inductive approaches. For example, facilitators and researchers may form a set of coding categories upfront based on agroecological principles (AEPs) (FAO, 2018; HLPE, 2019). This is in line with a deductive approach. Additional categories are added to these categories based on participant responses that were not adequately covered by the AEPs, which is consistent with an inductive approach. Thereafter the analysis is straightforward. The categories assigned the most hotspots—sustainability aspects rated 10 and higher—represent the most pressing areas to enhance sustainability along the VC in question. Local research collaborators are strongly recommended to be involved when applying the pHSA. Firstly, to ensure the study approach is firmly rooted in the local context, and secondly, to facilitate communication with participants in vernacular. In rural areas, some participants may find it easier to open up and express themselves more comfortably if they can use their local dialect or language.

3.3. Scale of assessment, data collection, and sampling methodology

In 2021, the Green Innovation Centers (GIC) of Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ) supported about 3,500 dairy farmers, of which 21% were female farmers, organized into 24 cooperatives within 7 districts of the Southern Province. The coop members sold their milk into the formal market through milk collection centers. In 12 districts of the Eastern Province, the GIC supported about 107,000 groundnut farmers, of which 54% were female farmers, organized into 54 cooperatives (GIZ-GIC 2021). These coops were linked to the social enterprise COMACO, through which they marketed their produce. In total, we conducted 9 FGDs with farmers from these two groups. Table 1 provides an overview of our entire data collection. In the dairy sector, we conducted 5 FGDs, while in the groundnut sector, we conducted 4 FGDs. As we began testing our methodology in the first FGD with participants from the dairy sector, and then applied most of the *ad-hoc* adjustments in subsequent data collection sessions, we conducted an additional FGD in this sector. Volunteers for transect walks and seasonal calendars were recruited on the spot from communities in which the FGDs were conducted. The identification of participants for the FGDs was facilitated by the staff of GIZ-GIC and their partner COMACO. We perceived any selection bias or conflict of interest to be negligible. Participants for the key informant interviews and the validation workshop were identified by purposive sampling.

3.4. Data processing and analysis

The information from the evaluation cards, notes, and FGD participants (e.g., gender and location) were transferred to Excel spreadsheets for analysis. We coded the responses from the FGDs using deductive and inductive methods to strike a balance between ensuring some degree of standardization, and thus allowing a comparison to be made between results from different FGDs and the AEPs, as well as accurately capturing the livelihood situation of our participants. For example, we checked which AEP covers a particular sustainability aspect identified by our participants. If that AEP fitted well, we used that term as a code for the sustainability aspect. If not, we defined a new code term for that issue based on input from the participants. Then, the identified and evaluated sustainability threats were assigned to corresponding sustainability aspects. All aspects that

1 Free online audience engagement platform - https://www.mentimeter.com.

TABLE 1 Summary of data collection activities and participants.

Method	Focus group discussions			Transect walks & seasonal calendar	Key informant interviews	Validation workshop
Value chain	Women	Men	Youth			
Dairy	23	38	29	3	16	19
Total	90					
Groundnuts	31	32	26	6	19	
Total	89					

Own data.

received one or more threats with a score higher than 10 were treated as a sustainability hotspot and reported on in Tables 2, 3. No statistical analysis was undertaken.

4. Results from the dairy and groundnut VC case studies in Zambia

Tables 2, 3 provide a summary overview of the sustainability aspects that participants identified, and the number of threats rated as sustainability hotspots relating to those sustainability aspects. In the dairy VC, participants identified 19 sustainability aspects compared to 15 in the groundnut VC. However, the number of threats rated as hotspots was almost double in the dairy, compared to the groundnut VC—60 and 33, respectively. Nevertheless, the identified sustainability aspects in the social, ecological, and economic dimensions were very similar or the same in both VCs. For example: "Knowledge sharing" and "knowledge and adoptions of CA" in the social dimension; "stable rain patterns" and "environmental protection" in the ecological dimensions. In the economic dimension, quality issues—such as "product quality," "quality standards," and "quality monitoring," as well as issues around "profitability" and "viability of the VC," were shared concerns in both VCs. It is worth noting that under "environmental protection," the "cutting of trees" for charcoal production, and resulting deforestation, was an equally strong concern—rated five times as a hotspot in each VC. However, participants in the dairy VC included the threat of "weak governments/chiefs" as a concern. The sustainability aspects "access to inputs, land, capital," and issues around alternative economic opportunities—e.g., "economic diversification" and "employment opportunities," were also identified in both VCs.

While there were shared concerns about sustainability aspects in both VCs, there were also distinct differences. As already alluded to, participants in the dairy VC had a much greater focus on the role of government. About a quarter of all hotspot threats in the dairy VC related to governmental service delivery, ranging from extension—such as poor accessibility and having to pay transport and lunch allowances to staff, to political marginalization, general funding constraints, and poor maintenance of transport infrastructure. While for groundnut farmers, only the latter point was mentioned in relation to the impact of government on their VC.

The other aspect that clearly stood out in the VC dairy farmers' hotspot assessments were gender relations issues—such as gender equality and youth empowerment. In addition to high prices for land acquisition, gender inequalities and customs were highlighted in the dairy VC as an aggravating factor regarding "access to land." Groundnut farmers also identified "access to land" as a problem, but the factors leading to this differ and do not relate to gender issues; instead, "overpopulation" and a lack of available suitable arable land are cited as causes. The gender bias within the two VCs is also reflected in the different ratios of male to female farmers engaging in the dairy and groundnut VC. As mentioned above, there was 21 and 54% female farmer participation in the dairy and groundnut VC, respectively. Also of significance was "jealousy," which was rated as a hotspot by participants in both VCs. However, it came up in somewhat different contexts, i.e., under different sustainability aspects, namely "knowledge sharing" in the dairy VC and "community cooperation" in the groundnut VC.

5. Discussion

5.1. Performance of the pHSA in our case studies

Sustainability is a very broad and multi-layered topic, and its definition is intensely and controversially discussed in academic and political circles (Tulloch and Neilson, 2014; Elkington, 2018; Bruckmeier, 2020). To engage in a meaningful way with smallholder farmers in sub-Saharan Africa on the many aspects of sustainability, one must break this complex issue down to the living realities of the people concerned, and start addressing real-life problems (Fraser et al., 2006; Stoian et al., 2012; Frank et al., 2022). We aimed to do that by placing emphasis on the basic resources farmers require to engage in dairy or groundnut production successfully. By taking the necessary resources as a point of departure for the sustainability assessment, farmers, i.e., our FGD participants, quickly became aware of the ecological, social, economic, and political systems surrounding them. Importantly, they also recognized the conditions for their continued functioning. Therefore, participants gained a holistic understanding of the interdependencies between different dimensions of sustainability and the situation as it related to their livelihoods.

The pHSA allows facilitators flexibility, which has proven useful in this step, as it allows participants to define terms in their own words and according to their understanding. This prevents later misunderstanding or confusion and, according to Bezner Kerr et al. (2019a), promotes reflection, discussion, and active participation. The fact that pHSA goes hand in hand with the goals of PAR (Participatory Action Research) is reflected in the principles that both approaches follow. Namely, people's interests come first, and the goal is specifically to include people's perspectives on a given issue, thereby empowering them to actively change a situation (Frank et al., 2022).

This is also supported by Fritz and Meinherz (2020), who discuss the value of participatory approaches in sustainability assessments in

TABLE 2 Sustainability aspects, threats, and hotspot rankings in the dairy value chain.

Phase	Dimension	Sustainability aspect	# of threats rated as hotspots
Production	Social	Government extension services	12
		Gender equality	4
		Youth empowerment	4
		Rent seeking by government authorities	2
		Knowledge sharing	1
		Community empowerment	1
	Ecological	Stable rain patterns	8
		Environmental protection (forests)	5
		Biodiversity	1
	Economic	Access to input	7
		Access to capital	5
		Access to land	2
		Economic diversification	1
Aggregation	Social	Governance at MCC	1
	Economic	Milk quality	2
		Transport	1
		Economic viability	1
Processing	Economic	Milk quality	1
		Participation of local value chain	1
Total social hotspots in the entire value chain			25
Total ecological hotspots in the entire value chain			14
Total economic hotspots in the entire value chain			21
Total hotspots in the entire value chain			60

Data from FGDs and KIIs.

TABLE 3 Sustainability aspects, threats, and hotspot rankings in the groundnut value chain.

Phase	Dimension	Sustainability aspect	# of threats rated as hotspots
Input	Social	Access to land	2
	Ecological	Quality seed	3
Production	Social	Community cooperation	6
		Knowledge and adoption of CA	3
	Ecological	Environmental protection (e.g., forests, soil, water)	5
		Stable rain patterns	2
	Economic	Employment opportunities	2
		Demand	2
		Access to capital	1
Aggregation	Economic	Mobility	2
		Honesty	1
Processing	Economic	Quality standards	1
		Storage capacities	1
		Quality monitoring	1
Marketing	Economic	Profitability	1
Total social hotspots in value chain			11
Total ecological hotspots in value chain			10
Total economic hotspots in value chain			12
Total hotspots in entire value chain			33

Data from FGDs and KIIs.

facilitating a shift from "power over" (i.e., coercion and manipulation, – such as external experts prescribing solutions), to "power to" (i.e., resistance and empowerment—such as the political process helping marginalized societal groups gain the ability to act), and eventually create the opportunity for "power with" (i.e., cooperation and learning, such as co-creation of knowledge). Our field study is a good example of inherent power structures that can prevent participatory approaches from reaching their potential—if they are not adequately recognized and addressed through good facilitation, such as that provided by pHSA. For example, membership in dairy cooperatives (Fritz and Meinherz (2020), and GIZ-GIC 2021), as well as participation in our FGDs (see Table 1, above) was skewed towards men in Southern Province. Interestingly, despite this gender imbalance, gender equality became an important topic of discussion in Southern Province among dairy farmers. In Eastern Province, where gender balance was a lot more pronounced, the topic was less discussed. This underlines once again that it is not enough to increase the number of participants of a marginalized group in the form of a quota in order to address their concerns adequately. Rather, skillful facilitation should be employed to sensitize dominating groups about concerns of marginalized ones, as the pHSA was able to demonstrate in our case study.

We argue that this method can shed light on the understanding and perception of sustainability of those people who are to be the focus of the analysis, as well as on the complexity and multidimensionality of sustainability itself. We assume this is necessary to understand the complexity of the underlying problems and adapt interventions accordingly. Or in the words of Fraser et al. (2006): "Since it is impossible to ensure that indicators chosen by 'development experts' will be relevant to local situations, local input is necessary to ensure indicators accurately measure what is locally important." Furthermore, the early involvement of local actors may help strengthen their agency and empowerment. In fact, evidence shows that local engagement helps strengthen the community's ability to address future problems (Fraser et al., 2006).

The importance of bringing in different perspectives, how existing intrinsic power relations function, and how sensitively they have to

be taken into account in the interaction with stakeholders, became particularly clear in one example from the field study. On this particular occasion, the participants of a youth focus group discussion from the dairy VC were initially apprehensive about sharing their experiences and discussing their challenges with the facilitators. The reason given by the participants was that they were neither listened to nor taken seriously by the older male farmers, nor did they receive support from them in the form of knowledge sharing. This initial reluctance was only overcome through gentle yet persuasive encouragement, and the creation of a safe space in which they could share their experiences with peers. A lively debate ensued, with valuable insights gained by both participants and researchers. In addition, such experiences can help strengthen self-esteem and a sense of community within the group (Droppelmann et al., 2022). The feedback from a lead farmer of a groundnut farmer group we interacted with in Eastern Province offers another example of participants' appreciation for the pHSA approach. Over and above the usual courtesy and multiple 'thank-yous' at the end of the FGD day, this lead farmer sent a note to the COMACO area coordinator, saying how helpful the day was. He specifically appreciated the opportunity to discuss sustainability challenges in his community, and create awareness of potential underlying interdependencies between sustainability aspects (Droppelmann et al., 2022).

In their review, Utter et al. (2021) point out that: "farmer-centered processes encourage knowledge co-creation that captures the interests and needs of farmers. This is important in terms of equity, and because farmers are key agents and critical actors in defining the interventions, resources, and new knowledge they need for sustainable livelihoods." The authors extend this argument even to cases in which co-creation was not explicitly planned at the outset of the process, such as Bezner Kerr et al. (2019b)—recommending the inclusion of AEPs that have local relevance in the farmer-researcher co-creation efforts. Fraser et al. (2006) also conclude that: "The process of engaging people to select key [sustainability] indicators provides a valuable opportunity for community empowerment and education. It is not necessary that this process be initiated from the bottom-up, but it is important that local stakeholder input be allowed to drive the process." The application of the pHSA in the field study has demonstrated that this approach offers the opportunity to achieve all these conditions.

Our results also demonstrate that farmers perceptions across the different dimensions and about specific aspects of sustainability do correspond to the AEPs as set out by the HLPE (2019). This thereby ensures their transferability to and comparability with similar assessments of other VCs—even within different countries. The pHSA takes the perspectives and perceptions of all actor groups along a VC into account. The validation of preliminary results from the FGDs and key informant interviews by local experts from supporting agencies and governing institutions, ensures the comprehensiveness, relevance and validity of the assessment from a local perspective.

5.2. Application of the pHSA in the context of development projects

In support of the Millennium Goals and, subsequently, the Sustainable Development Goals, numerous development agencies, donors, and governments adopted the VC development approach to achieve poverty alleviation goals among vulnerable rural populations (Neilson, 2014). However, successful smallholder participation in VCs has proven to be notoriously challenging, for which Stoian et al. (2012) offer the following explanation: rural smallholder households usually follow diversified livelihood strategies, which place smallholders in conflict with VC approaches that require following specialized investment and production strategies. Similarly, a number of critical challenges revolve around community organization and collective action (Perret and Stevens, 2006; Ortmann and King, 2007). In our study, these include the management of communal rangeland (e.g., fodder production) and forest resources (e.g., charcoal burning), as well as water management issues (e.g., erosion control). All these issues play out at a landscape scale and require community, not individual, responses. Hence, VC support interventions need to be designed in a manner that dovetails with the overall livelihood strategy of participating individual smallholder households, while also fostering communal action. In this regard, the pHSA proved to fit in well with participatory approaches frequently applied in a development context. In particular, the level of detail the pHSA offers in identifying specific threats or indicators to monitor sustainability failures may support the identification and design of corresponding innovations in response to such challenges. Therefore, the actual potential of the pHSA may go beyond its application solely as an analytical tool. When it is used as part of a transformative VC development approach, it can lead towards effective co-learning and co-creation. Thus, it would also make a meaningful contribution to a sustainable transformation in food systems. South African experiences show that: "encouraging farmers to participate in technology development, taking account of local knowledge and making sound institutional arrangements are some ways to foster better integration of technology and innovation" (Ortmann and King, 2007). Utter et al. (2021) postulate that: "A farmer-centered approach is fundamental in achieving sovereignty in the agrifood system." However, farmers are not the only actors and stakeholders in a VC. To achieve a truly transformative change within the food system, all relevant groups need to be brought into the processes of sustainability assessment and co-creation of knowledge. This will eventually lead to the design of sustainability-enhancing innovations along the entire VC. The foundation of a successful co-creation process is the respectful interaction, commitment, credibility, and trust between involved parties—attributes that take time to nurture and build (Cash et al., 2003; Carolan, 2006; Hegger et al., 2012). The pHSA offers a starting point for such a process within a development context. Building the foundations for what Frank et al. (2022) refer to as a crucial factor for successfully applying newly gained knowledge. Namely, the guided experimentation that allows for the testing of contextualized ideas that have been gained through constructive communication forums of experience sharing and action-oriented practices. Therefore, follow-up measures need to be devised that bring these diverse actors and stakeholders together on a longer-term basis, and ensure the incorporation of scientific evidence in the design of innovations. This goes beyond the current scope of the pHSA.

5.3. Limitations of the pHSA

To guarantee the soundness of the recommendations based on the analysis of the results from the pHSA, as described so far, verification against available scientific evidence appears necessary. For example, at

no point in our research study was the issue of methane release from large ruminants and their contribution towards climate change mentioned (IEA, 2021). This issue is a global concern, and while its relevance may appear negligible to local VC stakeholders, VC support interventions geared towards sustainable development cannot ignore such facts. Another consideration is the high demand for water in dairy production and processing. In the case of Southern Province in Zambia, one has to ask: Can water resources be sustainably managed to sustain dairy production in the foreseeable future (Arndt et al., 2019)? Therefore, verifying recommendations from the participatory assessment against available scientific evidence is crucial. If necessary, steps should also be taken to broaden the perspective to different scales of space and time. Furthermore, knowledge co-creation and facilitation processes for sustainability assessments, such as the pHSA, need to consider potentially unbalanced power relations among the various stakeholder groupings along a VC (Pohl et al., 2010), and must have the tools and capacity to mediate between these.

In addition, special attention must be paid to terms such as 'indigenous knowledge' or 'local knowledge', which are also known to be key elements of agroecology. What researchers or practitioners have in mind when using these terms may differ greatly from what local farmers think. As a result of agricultural reforms, neocolonial practices, and economic models, local farmers have adapted to a form of agriculture characterized by monocultures, high use of chemicals, and profit maximization—often damaging the environment for lack of alternatives. Bezner Kerr et al. (2019a) highlight that when it comes to recovering knowledge about traditional practices which may have been lost or forgotten in the wake of these developments, sensitivity, respect, and recognition of inherent power imbalances and contradictions are required.

6. Concluding remarks

We developed and field-tested a participatory approach to the hotspot analysis in two VCs in Zambia. We incorporated agroecological principles and elements, as well as participatory methods, to capture the perspectives of all relevant stakeholders on sustainability aspects. We conclude that our participatory hotspot analysis, the pHSA, is a user-friendly sustainability assessment tool that provides an ideal starting point in the development process for co-learning and co-creation of knowledge, with the capacity to generate sustainability-enhancing innovations and actionable recommendations. Drawing on Heron and Reason (2008) and Frank et al. (2022), it should be stressed that shared learning and desired changes in action are more likely to occur when the knowledge gained is based on stakeholders' own experiences, and is properly understood as the result of a collaborative assessment process. The application of the pHSA enables the incorporation of stakeholders' own experiences, and thus provides insight into aspects that threaten the sustainability of VCs from a stakeholder perspective. Knowledge of these perspectives is essential, especially for development practitioners tasked with formulating implementation strategies to improve VC sustainability. To further strengthen the transformation process of the food VC, we recommend that the impact evaluation of innovations—developed through the use of the participatory hotspot analysis—also be aligned with AEPs of co-creation of knowledge.

López-García et al. (2021) call for: "a more complex and renovated approach to agroecological, participatory research." To that end, field-testing the pHSA demonstrated its potential to become a valuable element in such an approach. It also proved its applicability in a development context. It produced robust, transferable results in line with AEPs, and offers a starting point for the co-creation of knowledge in support of transformative food VCs. Through the pHSA methodology, all relevant actor groups along a specific VC, as well as other stakeholders—such as supporting agencies and governing institutions, are involved in the sustainability assessment. The in-built validation and verification through subsequent scientific 'review loops' ensure that recommendations based on the assessment are locally grounded and scientifically based. We recommend the application of the pHSA as part of the planning process of VC development support interventions. We further recommend building on the participatory processes initiated by the pHSA in co-learning and co-creation of knowledge around sustainability-enhancing innovations. Doing so will ensure the full potential of the pHSA to contribute towards transformative food system change can be realized. Thus, sustainability assessments applying the pHSA could not only help achieve levels 1 to 3 of Gliessman's (2016) proposed agroecological transformation (i.e., efficiency, recycling, regulation, diversity, synergies, and resilience), but also contribute towards realizing levels 4 and 5 (i.e., co-creation of knowledge, culture and food transition, circular economy, human and social values, and responsible governance).

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

KD was affiliated to Picoteam Ltd at the time this manuscript was prepared.

The remaining author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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EDITED BY
Silke Maria Stöber,
Humboldt-Universität zu Berlin, Germany

REVIEWED BY
Sinead Boylan,
Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia
Katharina Löhr,
Leibniz Centre for Agricultural Landscape Research (ZALF) e.V., Germany

*CORRESPONDENCE
Ghassan Baliki
✉ baliki@isdc.org

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Home garden interventions in crisis and emergency settings

Ghassan Baliki[1,2]*, Dorothee Weiffen[1,2,3], Gwendolyn Moiles[2] and Tilman Brück[1,2,3]

[1]ISDC—International Security and Development Center, Berlin, Germany, [2]Leibniz Institute of Vegetable and Ornamental Crops (IGZ), Großbeeren, Germany, [3]Humboldt-University of Berlin, Berlin, Germany

Homes gardens are a key source of food security and micronutrient-rich fruits and vegetables and are promoted by aid organizations to help households cope in humanitarian emergencies. However, there is a strong divide between the popularity of home gardens among practitioners and the academic evidence of its nutritional, economic, social and political outcomes. This review provides a comprehensive summary of the evidence about home garden interventions in crisis settings using a three-pronged approach, triangulating evidence from academic literature, expert discussion (*World Café*) and a practitioner survey. Our findings show a significant gap between existing research evidence on one hand, and the needs and current practices on the other, particularly where theories and impact pathways of home garden interventions might not hold in crises-affected settings.

KEYWORDS

home garden intervention, crisis setting, humanitarian emergencies, impact evaluation, food security, World Café

1. Introduction

Home gardening has been an essential component of food and nutrition security for millennia (Galhena et al., 2013) and is key to realizing the economic and nutritional potential of vegetables (Schreinemachers et al., 2018). Also known as kitchen, backyard, farmyard, compound or homestead gardens, home gardens consist of regionally-appropriate crops grown on small plots of land or in containers adjacent to a living space. Other forms of small-scale, hyper localized vegetable and fruit production include school, community and urban gardens.

Home garden interventions (HGIs) require low inputs in terms of time, space and labor and hence lower budgets compared to many other development interventions; they also have a vast geographical range given the large scope of climatic conditions that support the cultivation of local flora (Galhena, 2021). Agricultural aid and humanitarian organizations implement HGIs with multiple objectives around the globe and often develop their own unique guidelines and systems for the provision of seeds, tools and training (e.g., Helen Keller, Mercy Corps, and Welthungerhilfe). HGIs also contribute to several Sustainable Development Goals, including zero hunger (SDG2), healthy lives (SDG3), the end of poverty (SDG1), gender equality (SDG5) and peace and justice (SDG16).

HGIs in settings not affected by conflict or other types of humanitarian crises have been shown to help strengthen nutritional security and buffer local food systems from global shocks (Galhena et al., 2013). Although HGIs are often implemented to help households cope in a variety of crises (e.g., climate, environmental, economic, political, violent conflict), little is known about the operational, social, economic and nutritional impacts of HGIs in *humanitarian emergency or conflict-affected settings* (HECS). HECS is a broad term we use to describe contexts

experiencing violent conflict, political and institutional fragility, displacement, and humanitarian and climatic emergencies, all of which are causally linked to severe food insecurity (Brück and d'Errico, 2019; Soffiantini, 2020). These settings require special attention given their unique conceptual, institutional and programmatic constraints (Maxwell et al., 2012). In such settings, food systems are often weakened or destroyed, access to nutritious food is severely limited (Martin-Shields and Stojetz, 2019), food production and livelihoods are undermined (Holleman et al., 2017), and households are at risk of experiencing protracted nutritional and economic crises (Laborde et al., 2021). Hence, violent conflict remains the main driver of food crises and nutritional insecurity and 80% of stunted children worldwide are countries affected by food crises (FSIN, Food Security Information Network, 2022). The United Nations Office for the Coordination of Humanitarian Affairs estimates that in 2023 339 million people worldwide will be directly or indirectly affected by humanitarian emergencies and will be in need of aid (OCHA, 2022).

Although HGIs are implemented worldwide in an array of different settings, a lack of data and rigorous empirical evidence from different contexts (including HECS) preclude a comprehensive understanding of best practices and impact pathways in crisis settings. HGIs are highly contextualized and nuanced, meaning strict statements about specific impact pathways or highly homogenized program structures would be unhelpful. It is nevertheless important to understand overarching theories of change and general best practices to ensure HGI success even in challenging conditions.

Given the lack of rigorous research about HGIs in HECS, it is *a priori* unclear if HGIs can be an effective tool to achieve food and nutrition security goals in crisis contexts. On the one hand, home gardens can function in isolation from markets; require low physical input; have short growing seasons; and require minimal land use and access. On the other hand, a certain amount of basic knowledge and experience is required to start and maintain a successful home garden; high-quality seeds may be unavailable in crises settings; agricultural extension advice may be difficult or impossible to attain; access to water and irrigation can be severely limited; even in crisis settings labor supply may be severely curtailed; and nutrition allocation decisions between and within households may be even more gendered in times of crises than in peacetime (Akter, 2021).

This paper reviews HGIs in HECS, thus identifying key issues and knowledge gaps as well as providing a roadmap for future research on the impact of HGI in HECS. We employ a three-pronged approach for this review. First, we survey the state of the art about the impacts of HGIs through a comprehensive academic literature review. Second, we observe current implementation practices through an online survey of HGI in HECS. Third, we use insights from World Café discussions conducted at the *Home Gardens for Resilience and Recovery* (HG4RR) Network[1] to broadly explore HGIs in HECS in terms of expected outcomes, best practices and knowledge gaps.

Across these three approaches, we find a disconnect between practitioner communities, which tend to develop programs in HECS, and academic communities, which tend to study programs in non-HECS. However, it is not known whether pathways in non-HECS are replicable in volatile and emergency settings. Instead, we posit that there may be alternative impacts and best practices in HECS that remain underexplored and mostly untested. Additionally, we identify key knowledge gaps about how HGIs in HECS might affect non-nutritional outcomes like women's empowerment, psycho-social wellbeing, peacebuilding, and social cohesion. Despite the effort of practice organizations to implement HGIs in HECS with learning components, there remain significant knowledge gaps for the research community to address.

This review paper is structured as follows: the next section outlines our research approach and methods. Section 3 explores the main findings. The discussion in section 4 conceptualizes impact pathways of HGIs in HECS and synthesizes main themes. In section 5, we conclude by highlighting opportunities to bridge the disconnect between research and practice and to close recognized knowledge gaps.

2. Materials and methods

We used a three-pronged approach, including a comprehensive literature review, a practitioner online survey, and World Café discussion with experts to generate a multi-angled snapshot of what is currently known about HGIs in HECS. First, we undertook a comprehensive literature review using Scopus of relevant qualitative and quantitative articles on impact evaluations of HGIs published between the years 2000 and 2023. We applied three combinations of key search terms including "home garden*," "kitchen garden*," "vegetable garden*," "homestead garden*," "home-stead garden*" or "school garden*"; "crisis," "crises," "emergenc*," "conflict*," "shock*" or "disaster*" and "impact evaluation*" or "impact assessment*" on 22 March 2023. We compare the results with the findings on scopus using the same search but excluding the key search terms on crisis and emergency. Complementary, we conducted the same research on Google Scholar, which also includes gray literature but does not allow a nested search.

We manually screened and sorted through these articles to determine relevance based on the following inclusion criteria: (i) Studies clearly specify impacts and outcomes at the household level; (ii) interventions focusing on homestead gardening; (iii) studies have a clear identification strategy, use rigorous quantitative methods, and adopt experimental or quasi-experimental designs; (iv) studies conducted in a HECS and (v) articles are written in English. Moreover, we compare the findings of this literature review vis-à-vis other academic work on HGIs in non-HECS settings. The intention of the literature review is to create a snapshot of academic consensus rather than to generate a systematic review of all research on home gardens interventions, as has already been done (Fiorella et al., 2016; Pandey et al., 2016; Ruel et al., 2018; Dizon et al., 2021; Dominguez-Hernandez et al., 2022). Hence, our comprehensive literature review compares this overall research body with the results that we extract based on crisis and emergency settings.

Second, to enrich our understanding of contemporary HGIs, we conducted an online survey of practitioners engaged in HGIs in HECS. The survey took place between 1 and 31 October 2019 and

1 The HG4RR network is a group of home gardening practitioners, experts, policy-makers, and researchers from the Global North and South operating under the auspices of the Leibniz Institute of Vegetables and Ornamental Crops (IGZ) in Großbeeren, Germany, and ISDC—International Security and Development Center, based in Berlin, Germany.

included 103 existing and planned programs from 36 organizations. Questions focused on program duration, country of operation, program outcomes and the type of emergency setting. The survey was circulated by email to members of relevant global networks and organizations identified through desk review.[2] Since there is no global catalog of HGI programs, we relied on a snowballing technique for survey distribution: respondents were asked to share the survey with their networks and invite at least two other stakeholders to take part. This technique has a sampling bias and tends to underrepresent small organizations with limited outreach or governmental support. We do not claim that our sample is representative of all existing practices; however, given the geographic and programmatic breadth of the responses, we are confident that our findings provide important insights.

Third, we uncovered knowledge gaps about HGIs in HECS through the "World Café" method with 40 experts at the HG4RR Network Workshop in Bonn, Germany which took place in April 2019. World Café is a participatory research method that engages large groups of stakeholders in free-form conversation and knowledge exchange to produce meaningful dialog (Lorenzetti et al., 2016) as well as qualitative data (Löhr et al., 2020). Participants were assigned to one of six breakout groups with balanced representation of gender, academic background and sector, and sat at round tables resembling a café. The groups discussed a series of questions in 20-min rounds, sharing insights from their discussions with other groups and taking notes in each group. The following six questions were discussed in as many rounds: (i) How can home gardens help households in crisis? (ii) What current or historical examples of home gardens or home garden interventions have worked well? (iii) Which external factors can help or hinder program impacts? (iv) Which program components are critical for achieving impacts? (v) What remain the key knowledge gaps? (vi) What are emerging research opportunities? These questions were designed to stimulate conversation about complex issues, advance basic understanding of home gardening in HECS, and help researchers and practitioners identify best practices, contextual barriers, opportunities for success, and knowledge gaps. The discussions were not intended to comprehensively represent all HGI mechanisms or outcomes but rather a broad reflection of the ideas and perceptions of the workshop participants that will help lay the groundwork for future cross-disciplinary discussion, research and intervention. The world cafe took place over the course of the day and was moderated by the research team. Each group produced a variety of handwritten material that was collected and transcribed. We organized this material by theme, summarizing the main concepts that developed across all groups.

2 Including the USAID-funded Food Security and Nutrition Network (FSNN), a global community of food and nutrition security practitioners; Agrilinks, an online group of food security and agricultural development practitioners overseen by the US Government's Global Hunger and Food Security Initiative; the Platform for African European Partnership on Agricultural Research for Development (PAEPARD), which supports agricultural research and development partnerships between Europe and Africa, supported by the EU through its Food Security Thematic Program; and Agriculture-Nutrition Community of Practice (Ag2Nut), part of the United Nations System Standing Committee on Nutrition.

3. Results

In this section, we present our main findings to correspond with the three distinct research methods. Table 1 provides an overview of the results which highlights which outcomes were addressed in the literature and which are considered important by the practitioners and the experts. The results show that although the research and evidence have made considerable progress in studying the impact of home garden interventions on multiple outcomes in non-HECS, practitioners are implementing similar programs in HECS that remain vastly understudied.

Figure 1 visualizes the findings from the three methods at the country level, focussing on Africa and Asia. Countries included in the practitioner survey represent HGI in practice, and countries included in our literature review represent countries included in the literature. We used the Fragile State Index as a proxy for the existence of (humanitarian) crises, which takes a value of 0 and 120 based on multiple social, political and economic indicators to measure country risk and vulnerability (Fund for Peace, 2021). The map shows that the higher the fragility index in a given country the less likely the evidence generated in the literature. Most evidence stems from countries, which have a fragility score of 80 and below (e.g., India, Bangladesh, Kenya, Tanzania, and South Africa). Furthermore, most countries with a fragility score higher than 100 that were present in the practitioner survey, were not covered in the literature, suggesting a disconnect between practitioner and academic interest and lack of academic understanding about more fragile settings (e.g., Afghanistan, Chad, Somalia, and South Sudan).

In the rest of this section, we present the findings from each of the approaches in detail.

3.1. Literature review

Our main query method on Scopus produced 242 articles which were largely overlapping with the results from Google Scholar. Excluding the HECS key terms, our search produced 599 results. We did not identify any article from Scopus that covers a rigorous impact evaluation on the household level of a homestead gardening intervention in a HECS in the English language.

However, emerging rigorous studies from HECS of vegetable seed transfer interventions (not explicitly HGI), show positive impacts on food security, nutritional outcomes and resilience (e.g., Baliki et al., 2018, 2022a; Kayaoglu et al., 2023) but lack assessments on other outcomes. Conflict clearly shapes the effectiveness of these support types (Weiffen et al., 2022), which underscores the lack of comparability between HECS and non-HECS. The absence of peer-reviewed research articles of HGI in HECS highlights the strong scarcity of evidence on the impacts of home garden interventions in such settings to date. Next, we discuss this gap considering other literature in non-HECS settings.

There is a nascent but growing body of research that uses rigorous assessment methods to study outcomes and impacts of nutrition-sensitive agricultural interventions like home gardens (e.g., Ruel et al., 2013; Schreinemachers et al., 2017; Baliki et al., 2019, 2022b). However, expected impact pathways of HGI are difficult to generalize given the heterogeneity of intervention tools and contexts (Fiorella et al., 2016). For example, while for many

TABLE 1 Summary of evidence on home garden interventions in humanitarian settings by outcomes from the three-pronged approach.

HGI outcomes	Literature review (HECS)	Literature review (non-HECS)	World cafe	Practitioners survey
Access to healthy food	✓	✓	✓	✓
Dietary diversity	✓	✓	✓	✓
Resilience	✓	✓	✓	✓
Women empowerment	X	✓	✓	✓
Income generation	X	✓	✓	✓
Psychosocial well-being	X	✓	✓	✓
Peacebuilding	X	X	✓	✓

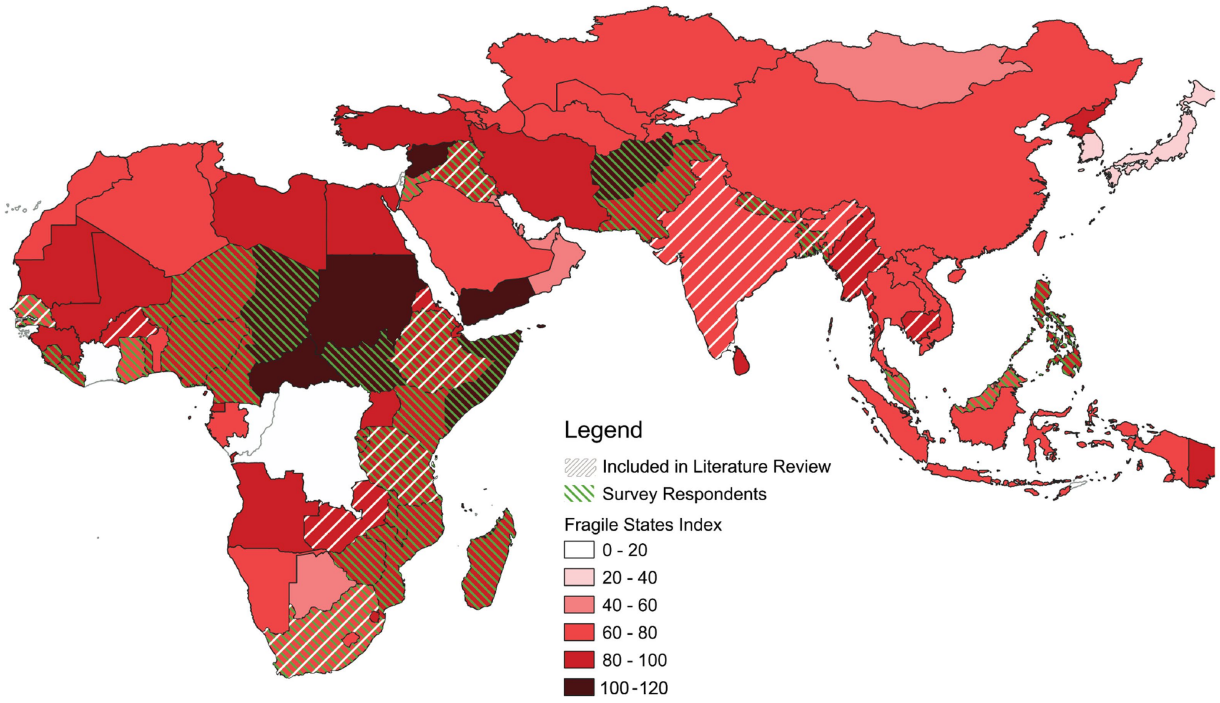

FIGURE 1
Home garden interventions: how literature, practice, and context align.

Asian countries the literature provides evidence on HGIs increasing vegetable production, in Kenya and Uganda, households did not increase their vegetable production substantially through HGIs (Baliki et al., 2019, 2022b; Bird et al., 2019; Depenbusch et al., 2021, 2022). We found three major areas where HGIs have been found to have had measurable impacts on development goals: direct nutritional benefits, behavioral changes in terms of food choices, and women empowerment.

The direct nutritional benefits of HGIs are often a key point of investigation since HGIs are often conducted to improve household dietary diversity and access to micronutrients (Pritchard et al., 2019). Studies have shown that HGIs help increase consumption of nutrient-rich vegetables, including indigenous vegetables and leafy greens, in a number of countries in the Global South including Bangladesh (Bushamuka et al., 2005; Schreinemachers et al., 2016; Baliki et al., 2019, 2022b), Burkina Faso (Olney et al., 2016; Schreinemachers et al., 2019), Cambodia (Dragojlovic et al., 2020; Depenbusch et al., 2022), India (Murty et al., 2016), Nepal (Osei et al., 2015, 2017), Tanzania (Blakstad et al., 2021, 2022) and Zambia (Kumar et al., 2018). The scarce literature on long-run nutritional impacts paints an ambiguous picture: while effects are sustained over a long period of 6 years in Bangladesh (Baliki et al., 2022b), impacts vanished in Tanzania (Blakstad et al., 2022). Although home gardens interventions have been linked to increased dietary diversity and improved consumption of nutrient-rich foods, there is little conclusive evidence that HGIs strongly influence overall household food security (Blakstad et al., 2021).

HGIs are also associated with behavioral changes in production and consumption in some settings, although short-term changes are unlikely to be sustained if implementation strategies fail to alter eating habits (Baliki et al., 2019, 2022b). For example, integrated school and home gardens were only found to have a measurable impact on children's vegetable consumption when combined with nutritional training for parents and caregivers (Schreinemachers

et al., 2020). An integrated approach combining nutritional knowledge, hands-on-training, the provision of seeds and tools, and continuous follow-ups by trainers have been shown to increase total production of vegetables grown in home gardens, such as leafy greens (Olney et al., 2016).

There are many non-nutritional impacts of HGIs that have received academic attention at the community, household, and individual levels. In households that grow an abundance of produce, selling excess or specialty foods can be an important source of supplementary income, increasing household purchasing power and indirectly improving food security through the purchase of other stable foods (Weinberger, 2013). Moreover, home gardens build up household resilience against crises like COVID-19 (Carstens et al., 2021). Finally, we find indicative evidence that community vegetable gardens can contribute to social cohesion through community engagement and organization (Veen et al., 2015) and gardening has been found to contribute to physical and emotional wellbeing in stressful and uncertain environments like refugee camps (Hartwig and Mason, 2016; Tomkins et al., 2019). The rigor of the studies that focus on non-nutritional impacts, however, remains very weak.

Another well-studied impact of HGIs is their potential to influence gender roles. Women's control of resources and decision-making is often compromised in patriarchal rural societies (Sraboni et al., 2014) but women usually play the dominant role in food preparation (Quisumbing et al., 1996) and tend to have more autonomy in home gardens (Hillenbrand, 2010; Patalagsa et al., 2015; Rybak et al., 2018). Distinct yet gradual signs of shifting gender dynamics have been observed as women received recognition because of home garden training. Since home gardens do not radically challenge traditional gender roles, women are able to incrementally gain control over income and food provision and gain self-confidence and recognition for their skillset (Patalagsa et al., 2015; Baliki et al., 2019, 2022b; Bliznashka et al., 2022). Women engaging in home gardening can improve their economic participation by bringing excess produce to markets where they can generate income and increase their influence in household decision-making, thereby improving their access to and control over resources (Bushamuka et al., 2005). Furthermore, women's economic empowerment and improved bargaining power tend to positively affect child nutritional status (Cunningham et al., 2015; Malapit et al., 2015; Santoso et al., 2019). Thus, home gardens can reinforce household nutrition both directly through the provision of fresh produce and indirectly through women's economic empowerment. However, the input of physical labor and time required for gardening activities can also add additional challenges to women's daily lives (Kjeldsberg et al., 2018). Since HGIs often target women who already carry the bulk of household labor, such interventions may reduce time available for childcare, healthcare, food preparation, and/or leisure (Cunningham et al., 2015; Carletto et al., 2017).

In summary, HGIs in non-crisis settings have been found to induce a variety of impacts including access to healthy food, dietary diversity, resilience, women empowerment, income generation and psychosocial well-being, see Table 1. However, little is known about how HGIs are influenced by external social, political, or environmental disruptions and crises, although studies in other domains have certainly explored the crossroads of conflict and food insecurity (Holleman et al., 2017). Evidence at the nexus of humanitarian emergencies and food insecurity includes access to micronutrients (Brück et al., 2019; Brück and d'Errico, 2019) and childhood stunting (Akresh et al., 2012), but there is no evidence that directly links HGIs to food security or non-nutritional impacts in HECS.

3.2. Home gardens intervention in practice

Here, we present the findings from a practitioner survey of 103 home garden programs led by 36 organizations operating in 39 countries in the year 2019. Thirty four of the stated programs were still in the planning phase at the time of the survey, hence, we will only present the findings from the remaining 69 programs which were either still ongoing during the time of the survey or have been completed. HGIs were implemented by a range of diverse actors including three government-backed organizations, nine universities from both the Global North and South, 14 local or international NGOs, and seven consulting firms and other agencies.

3.2.1. Types of home garden intervention

The survey covered HGIs in three broad regions: sub-Saharan Africa (SSA),[3] Middle East and North Africa (MENA)[4] and South and Southeast Asia.[5] 74.3% of programs in the total sample were implemented in SSA, 12.9% in Asia, and 12.9% in MENA. Two thirds of the HGIs were implemented in rural areas while 22% were in urban settings and 42% were in refugee camps.[6] A large proportion of the programs were implemented in recent years: 90% of the interventions took place since 2010 and over half were established after 2016. One third of the interventions were completed by 2019. On average, a HGI lasts for 3.6 years.

Table 2 shows the type of home garden, the training component and the target group for the overall sample across the three geographic regions. Kitchen gardens were the most prevalent (74% of HGIs), particularly in Asia (89%). Kitchen gardens were mainly implemented in refugee camps and rural areas while urban settings tended toward school gardens. Community gardens were most prevalent in the MENA region, targeting both displaced and non-displaced communities.

A training component was used in almost all surveyed programs (94%): 83% of all interventions included technical gardening training, 70% included nutritional training, 49% included WASH components, and 64% used a combination of training styles (multiple responses permitted). Nutritional training was not universally available: while 80% of HGI in SSA included nutritional training, only 56% reported to do so in Asia, and a mere 22% of programs involved nutritional training in MENA. These differences were statistically different at the 10% level. We find no notable differences in the type and frequency of training provided across various population settings.

3 Burundi, Cameroon, Central African Republic, Chad, Congo, Democratic Republic of Congo, Ethiopia, Gambia, Ghana, Kenya, Madagascar, Malawi, Mozambique, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Somalia, South Africa, South Sudan, Tanzania, Togo, Uganda, Zimbabwe.

4 Iraq, Jordan, "Kurdistan", Lebanon, Liberia, Sudan, Turkey – and Greece for simplicity.

5 Afghanistan, Bangladesh, "Kashmir", Nepal, North Korea, Malaysia, Pakistan, Philippines.

6 Given that a setting can have multiple characteristics, the cumulative shares do not add up to 100%.

TABLE 2 Training and targeting characteristics of HGI.

		Geographic region			Population setting		
	Overall	SSA	Asia	MENA	Urban area	Rural area	Refugee camp
n	69	52	9	9	15	47	29
Garden type							
Small kitchen gardens	74%	73%	89%	67%	67%	72%	79%
Large integrated HG	33%	29%	33%	56%	27%	36%	45%
Community gardens	51%	51%	44%	56%	53%	53%	45%
School gardens	32%	37%	22%	11%	60%	34%	17%
Training							
Any training	94%	92%	100%	100%	93%	94%	97%
Gardening training	83%	86%	67%	78%	73%	85%	79%
Nutritional training	70%	**80%***	**56%***	**22%***	67%	74%	76%
WASH training	49%	55%	44%	22%	60%	55%	48%
Target group							
Women	84%	88%	78%	67%	80%	94%	86%
Young children (<6)	28%	33%	11%	11%	33%	32%	28%
Children (6–12)	39%	43%	33%	22%	60%	43%	34%
Adolescents (13–18)	46%	51%	33%	33%	73%	53%	41%
IDPs	29%	24%	44%	44%	40%	26%	38%
Refugees	46%	41%	44%	78%	7%	38%	100%

As programs can be implemented in various settings, the cumulative shares do not necessarily add up to 100%. Values highlighted with * imply that the difference is statistically significant at 10% level using Pearson Chi-squared test.

We observe strong geographic differences in targeting (see Table 2). Programs in SSA prioritized women and young children while those implemented in MENA focused more on refugees and IDPs. Children above the age of six were more likely to be targeted in urban settings than in rural ones or in refugee camps, correlating with the prevalence of school garden interventions in urban settings.

3.2.2. Home gardens and crises

Table 3 summarizes the share of the HGI surveyed operating under five pre-defined crisis categories (climate, political, economic, protracted and health crises), which respondents classified by prevalence and severity. A majority of HGI operated in countries experiencing multiple simultaneous crises. On average, the countries face four out of the five pre-specified crises. 85% of HGIs in the survey were in settings experiencing protracted crises, 49% of which were classified as critical. At least one emergency type could be classified as high or critical in 71% of the countries where our survey programs are implemented, including 67% of the reported programs operating in countries experiencing severe economic emergencies. In the MENA region, 78% of the programs were implemented in areas experiencing climatic, political, economic, and protracted crises at the same time, and 67% of the programs were in IDP or refugee camps. Health crises were less prevalent in our sample than other emergency types, but it is worth noting that our survey was completed before the start of the COVID-19 pandemic.

3.2.3. Home garden intervention impacts

All the programs aimed to achieve multiple outcomes. Table 4 lists the major intended outcomes across our sample. These include: access to healthy food (81%), income generation (77%), women empowerment (75%), and dietary diversity (71%). Roughly 40% of the programs aimed to improve all four of these outcomes simultaneously. Other less common outcomes were strengthening resilience (62%), improving psychosocial well-being (38%), and peacebuilding (28%). On average, a program intends to achieve 4.3 out of the seven pre-specified outcomes. In terms of variation of program outcomes by region, we find that interventions which focused on women empowerment were more prevalent in Asia (78%) and SSA (80%) than in MENA (44%). Impact on dietary diversity was especially considered in programs implemented in SSA (78%) in comparison to Asia (56%) and MENA (44%), where diverse consumption of vegetables is traditionally higher than in SSA. Impacts on psychosocial well-being and peacebuilding were less prevalent, and with no strong differences across the regions.

The results of the survey reveal differences at the regional level among the participating HGIs. They also underscore universal themes across all regions in terms of target groups, contextual factors (i.e., presence and type of crisis), the inclusion of training and the type of intended outcomes (i.e., nutritional, social, economic, etc.).

3.3. World Café of home garden interventions

We next synthesize the main themes of the World Café discussions through a thematic analysis of transcribed notes (for guiding questions see section 2.3) with the purpose of highlighting factors and best

TABLE 3 Prevalence and severity of crises across HGI.

		Geographic region			Population settings		
	Overall	SSA	Asia	MENA	Urban area	Rural area	Refugee camp
n	67	49	9	9	14	46	29
Crisis of any severity							
Climatic	87%	84%	100%	89%	86%	89%	83%
Political	76%	71%	78%	100%	79%	72%	86%
Economic	90%	88%	100%	89%	93%	91%	90%
Protracted	85%	84%	89%	89%	93%	85%	90%
Health	75%	78%	56%	78%	86%	70%	69%
Crisis of high and critical severity							
Climatic	34%	33%	44%	33%	29%	33%	28%
Political	39%	37%	44%	44%	36%	28%	41%
Economic	67%	73%	44%	56%	79%	67%	55%
Protracted	49%	47%	44%	67%	57%	43%	52%
Health	24%	31%	0%	11%	21%	22%	17%

As programs can be implemented in various settings, the cumulative shares do not necessarily add up to 100%.

TABLE 4 Intended outcomes of the home garden interventions.

		Geographic region			Population setting		
	Overall	SSA	Asia	MENA	Urban area	Rural area	Refugee camp
n	69	51	9	9	15	47	29
Desired outcomes							
Access to healthy food	81%	80%	89%	78%	87%	81%	90%
Dietary diversity	71%	**78%***	**56%***	**44%***	60%	70%	86%
Resilience	62%	63%	67%	56%	60%	60%	79%
Women empowerment	75%	**80%***	**78%***	**44%***	93%	77%	66%
Income generation	77%	76%	89%	67%	87%	81%	76%
Well-being	38%	35%	56%	33%	67%	32%	31%
Peacebuilding	28%	25%	38%	33%	47%	22%	28%

As several programs can be implemented in various settings, the cumulative shares do not necessarily add up to 100%. Values highlighted with * imply that the difference is statistically significant at 10% level using Pearson Chi-squared test.

practices that are critical for achieving impacts of HGI in HECS and consequently identifying knowledge gaps.

The discussants talked through the dynamic influence of factors on HGIs, creating broad pathways that tether approaches and aims of HGIs to different types of HECS. We found the following key themes: climate/weather/environmental emergency settings that employ specialized garden designs to resist flooding or drought conditions; HGIs focused on ecological resilience and diversity in the face of pests and diseases; both income-generation and market-independence for settings experiencing economic crises; and community-building and identity-construction for groups experiencing mental health crises in violent or post-war settings.

Program success of HGI, according to World Café participants, is dependent on key components including existing household food and meal preferences, health consciousness, levels of knowledge about gardening, as well as adequate land and seed access, sufficient program duration, and the extent of the involvement of men in the intervention. Influential external economic and political factors included connections to research hubs, the local influence of agricultural cooperatives, the stability of governments and/or existing policies, the presence of or lack of cooperation and coordination between sectors, and access to government or nongovernmental program funding.

Regardless of the type of crisis, two important aspects were underscored in the discussions which were seen as fundamental to program success. First, a participatory planning and implementation approach was flagged as a key element for program success. Without the inclusion of target communities in the planning process, a program would likely fail to meet community needs and would not be sustainable. Practitioners and researchers equally agreed that this approach also requires the inclusion of multi-sectoral stakeholders and an interdisciplinarity to the program design. Second, a deep understanding of local context is equally crucial to achieve the intended outcomes of home gardens interventions. Understanding the specific needs of the target group would require learning how home gardening may be perceived in the community, how produce could be incorporated into dietary preferences, and how the garden would

impact household workloads or gender dynamics. How to approach these influences in times of stress, conflict, or violence remains a key knowledge gap.

Building on these elements, key knowledge and evidence gaps of HGI in HECS on multiple fronts have emerged.

First, in terms of program impact and mechanisms, there is still a lack of understanding on if and how home garden interventions contribute to social and political outcomes like peacebuilding, integration and cohesion. Moreover, how can interventions contribute to the maintenance of skills and traditions and food preferences in times of crises and what are the trade-offs that women participating in home gardens must make under such challenging settings?

Second, in terms of methods and approaches, it remains unclear what the best methods required to develop a more thorough understanding of short- and long-term impacts are, and how can reliable studies be designed and implemented in such difficult settings?

Third, in terms of multi-stakeholder collaboration, how can home gardens be sustainably funded and accessible to target groups in times of crises? And what ways to permanently bridge the gap between practitioners and scientists working in this field.

4. Discussion

Small-scale agriculture can be a vital crisis response strategy across humanitarian and development settings, and new evidence does explore home gardening's positive psychosocial and community impacts in refugee camps despite the lack of institutional support (Tomkins et al., 2019). However, and in line with Galhena et al. (2013), we have found little rigorous research that explored how outcomes observed in non-crises settings may function in active HECS. Suggestive evidence indicates that HGIs contribute to recovery after climatic shocks and conflict. However, strong evidence is still absent (Galhena et al., 2020).

Based on this key disconnect, we suggest future research on HGI in HECS to focus on sustainability and effectiveness – exploring how context influences impacts, including social and political impacts – with an integrated approach to practice and research.

4.1. Sustainability and effectiveness

The diversity of HGIs types and outcomes in different contexts compounded by unique institutional challenges of HECS makes this a complex area of research. Understanding the contextual factors of HECS that disrupt HGI efficacy is vital to creating more resilient and beneficial programs. With this review, we have identified existing evidence about HGIs and found that although HGIs are implemented widely in HECS, there is little evidence that interrogates program impacts and pathways in these settings. The variety of program goals and impact evaluation methods used by multidisciplinary researchers and practitioners working in these heterogeneous settings means there is little consensus in terms of best practices. On the other hand, the evidence on HGI from other development settings that do not fall within HECS is fine-tuning methods to look beyond immediate nutritional benefits at downstream social and economic impacts. Only a handful of studies have identified long-term impacts of HGIs, raising questions about their effectiveness and sustainability in highly volatile contexts such as HECS. Research about the long-term impacts is crucial to understanding whether interventions in HECS are sustainable in terms of cost–benefit, accessibility, and replicability.

4.2. Context matters

Within the practitioner and research communities it is understood that context is vital to understanding potential program impacts. Similarly, research on HGI has thus far ignored the contextual factors that might shape how program impacts are actualized and sustained. The lack of such analysis is likely to be detrimental to the design of future HGIs as it could underestimate the magnitude of HGIs as a coping mechanism against severe episodes of shocks and food insecurity.

4.3. Social and political impacts

While peace-building and social cohesion opportunities of HGIs in HECS were emphasized in the World Café discussions, the dominant motivations of the sampled programs were nutritional, economic, or empowerment-based. Impacts like resilience, well-being, and peacebuilding were observed in less than half of the interventions and peace-building was only targeted in 25% of observed programs. This suggests that HGIs in HECS are more focused on food security and reducing malnutrition than engaging in indirect psychosocial aims or that implementing groups rely on more tangible nutritional targets to achieve program funding. Since the non-nutritional aspects of HGIs are not primary features in program development, is it possible that they tend to be neglected in evaluation as well. Any significant impact on well-being and peacebuilding is likely to be underestimated if there are few empirical studies interrogating it. To ensure the achievement of the nutritional and food security goals, programs need to strengthen other outcomes and pathways beyond the plate.

4.4. External validity

The dominance of case-study-based evaluation and research implies that it is difficult to determine broad themes to lead to generic policy implications valid for HGIs across different settings. There is a lack of consistent assessment methods across HGIs in all settings, with only about one fifth of surveyed programs reporting the use of qualitative and quantitative impact assessment tools, and overall limited long-term impact assessment of HGIs after initial implementation.

4.5. Integrating research

World Café discussions helped bridge research-practice disconnects and illuminate opportunities for future research by

bringing practitioners and researchers together in conversation. This type of interaction should continue as key knowledge gaps in terms of implementation, impact, sustainability, and formulation of impact evaluation are addressed. Such information is fundamental to understanding how HGIs contribute to strategic food security goals, including global SDGs, in these vulnerable settings and will help future programs maximize positive impacts.

5. Conclusion

Home gardens are a simple, adaptable and often used tool to try and improve household access to micronutrients and provide tangential, yet potentially powerful, individual-, household-, and community-level impacts. In HECS with little institutional stability where individuals endure protracted duress and sustained trauma, HGIs could additionally contribute to empowerment and psychosocial well-being. The absence of a well-developed theory of change for HGIs in HECS impedes system-wide learning in the sector. However, core elements of such a theory would need to differ from non-HECS settings. This review underscores the need for more targeted empirical research that addresses multiple points along HGI pathways, including program implementation and long-term garden care and sustainability; the type inputs and support required in different HECS; the integration of contextual factors and the development of testable linkages between direct (nutrition and food security) and indirect (economic empowerment, psychosocial well-being, women's empowerment, intra-household and community gender relations) program effects and pathways. The lack of coherent assessment regarding implementation and impact of HGIs in HECS means that programs may be under-utilized or ineffective in these settings.

It is important to substantiate programming efforts with methodologically rigorous studies to ensure an effective human-scale response to food insecurity, micronutrient deficiency, and/or a tool for peacebuilding, empowerment, and knowledge-sharing. Rigorous research can be challenging in HECS, but improving or systematizing assessment techniques will help to explain how HGIs function in these settings and may contribute to improved design and greater impacts. Such evidence is crucial for future programming and development policy in the wake of the COVID-19 pandemic, which has disrupted food systems and increased food and nutrition insecurity worldwide. There is an urgent need for researcher-practitioner collaboration to generate evidence to improve the effectiveness of home gardening interventions in the future and accelerate the achievement of the Sustainable Development Goals.

Author contributions

GB and TB raised the funds and conceptualized the study. GB, DW, and GM collected and analyzed the data and drafted the text. TB supervised the study and reviewed and edited the text. GM also provided administrative support. All authors contributed to the article and approved the submitted version.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2023.1138558/full#supplementary-material

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EDITED BY
Isaac Gershon Kodwo Ansah,
University for Development Studies, Ghana

REVIEWED BY
Maria Rembiałkowska,
Warsaw University of Life Sciences, Poland

*CORRESPONDENCE
Samuel Elolu
✉ samuel.elolu@hu-berlin.de;
✉ elomuel@gmail.com

†These authors have contributed equally to this work

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Improving nutrition-sensitive value chains of African indigenous vegetables: current trends in postharvest management and processing

Samuel Elolu[1,2,3*†], Rachel Byarugaba[1,4†], Arnold Mathew Opiyo[3], Dorothy Nakimbugwe[4], Dagmar Mithöfer[5] and Susanne Huyskens-Keil[1]

[1]Faculty of Life Sciences, Division Urban Plant Ecophysiology, Research Group Quality Dynamics/Postharvest Management of Perishable Crops, Humboldt-Universität zu Berlin, Berlin, Germany, [2]Department of Food Science and Postharvest Technology, Faculty of Agriculture and Environment, Gulu University, Gulu, Uganda, [3]Department of Crops, Horticulture and Soils, Faculty of Agriculture, Egerton University, Njoro, Kenya, [4]Department of Food Technology and Nutrition, School of Food Technology Nutrition and Bioengineering, Makerere University, Kampala, Uganda, [5]Faculty of Life Sciences, Agrifood Chain Management Group, Humboldt-Universität zu Berlin, Berlin, Germany

The value chains of African indigenous vegetables (AIVs) are highly constrained by high postharvest losses (up to 50%) along the chain, largely occasioned by poor postharvest management and a lack of optimized processing technologies. The technologies and practices are key technical aspects that can transform the capacity of the chain by enhancing the overall value generated from the system. AIVs have recently experienced an increase in demand due to their high nutritional value and the opportunity they present to enhance rural incomes, since they are predominantly produced by smallholder farmers in rural and peri-urban areas. This implies that they can positively contribute to increased availability and hence supply of nutritious food within local food systems. Furthermore, the fact that half of the economic value of AIVs is potentially lost due to inappropriate postharvest management and inadequate processing demonstrates the potential that related interventions and transformations could have in enhancing and preserving value along AIV value chains. Currently, the approaches applied to reduce food waste, preserve nutritional quality, and add value to AIVs are largely traditional in nature. They require upgrading and need to be aligned toward achieving a nutrition-sensitive value chain. By looking at these as value creation processes, this mini-review examines the current postharvest management practices, highlights relevant new and innovative technologies and related challenges, and suggests potential options to improve the benefits for AIV value chain actors and thus contribute to a sustainable transformation of nutrition-sensitive food systems.

KEYWORDS

postharvest technology, processing, value chains, nutrition-sensitive, African indigenous vegetables

1. Background

Recent developments in the vegetable sector in Sub-Saharan Africa (SSA) have sought to increase the production and utilization of African indigenous vegetables (AIVs) (Imathiu, 2021; Bokelmann et al., 2022). AIVs are underutilized vegetables whose production and utilization are characterized by specific socioeconomic, technological, and market dynamics. AIVs include all plants that originate on the continent or have a long history of cultivation and domestication to African conditions and whose leaves, fruits, or roots are acceptable and used as vegetables through custom, habit, or tradition (Ambrose-Oji, 2009; Maundu et al., 2009; Uusiku et al., 2010). Examples of commonly consumed AIVs include, amaranth (*amaranthus cruentus)*, African nightshade (*Solanum scabrum*), African eggplant (*Solanum aethiopicum*), jute mallow (*Corchorus olitorius*), and okra (*Abelmoschus callei*). These vegetables are predominantly produced by rural and peri-urban smallholder women farmers, in a value chain characterized by poorly developed marketing systems concentrated in rural and peri-urban localities (Shayanowako et al., 2021). They are highly adapted to such local contexts and are prioritized locally for their nutritional and health benefits (Moyo et al., 2021). These vegetables do not only form an important part of the local food systems and diets in many rural African communities but they have also attracted wider global attention, leading to an increase in demand and production due to their high nutritional value and economic potential (Bokelmann et al., 2022). These observations imply that promoting AIVs can contribute to transformation of rural food systems, empowering smallholder farmers economically and strengthening the value chains for micronutrient-rich foods.

Despite increasing recognition of the potential of AIV value chains to enhance human nutrition and spur economic development, they remain generally underdeveloped and constrained by a number of factors such as (i) poor productivity, (ii) poorly organized marketing, (iii) lack of technologies and knowledge for sustainable processing, and (iv) high postharvest losses (Musebe et al., 2017; Owade et al., 2020; Hlatshwayo et al., 2021). Current literature indicates that up to 50% of the vegetables are lost at postharvest stage (Gogo et al., 2018b). On the other hand, although the actual proportion of leafy vegetables that is processed in SSA is not clearly documented, available literature shows that AIVs are predominantly consumed fresh (Maseko et al., 2018). The low level of processing is attributed to factors including; (i) lack of technology, (ii) lack of processing knowledge, and (iii) a low level of alternative utilization options for AIVs (Mazike et al., 2022). This translates into high levels of overall losses along the supply chains. For instance, Gogo et al. (2017) reported a loss of macro- and micronutrients and protein content between 3.2–29.4%, and chlorophylls and carotenoids between 70.9–90.9% and 70.4–91.9% respectively, along the supply chain of African nightshade in Kenya. This implies that besides the economic losses, poor postharvest management and a lack of processing also reduces the nutritional value of the AIVs.

Nutrition-sensitive value chains (NSVCs) are food systems that are more likely to improve nutrition by enhancing dietary diversity and nutritional quality. They are strategically positioned to enhance the supply of nutritious foods, add nutritional value, and enhance demand for nutritious foods along the chain (de la Pena et al., 2018). From several literature strands around NSVCs and AIVs (Brauw et al., 2015; Hodge et al., 2015; Wesana et al., 2018; Mazike et al., 2022), the potential role of postharvest management in transforming local value chains can be realized through four pathways: (i) reducing quantitative and qualitative food losses, (ii) extending shelf life and improving storage of vegetables, (iii) enhancing food safety, and (iv) optimizing preservation technologies for food nutritional quality. In this review, we summarize the actual knowledge on current postharvest management and processing practices, identify gaps, and indicate emerging approaches that could improve the nutritional outcomes of AIV value chains which contribute to food security.

2. Methodology

The study followed the narrative literature review approach as previously described by Ferrari (2015), and therefore synthesis of the review is presented in a narrative rather than statistical format. This approach was enhanced by including a systematic literature identification and search criteria so as to execute an effective search and minimize bias in the selection of articles for review. Briefly, the review criteria considered, (i) only articles that addressed the topics of postharvest management and processing of African indigenous vegetables, (ii) only peer reviewed articles published between 2003 and 2022; (iii) only articles in English language. To identify relevant available literature, specific search terms were utilized including "African indigenous Vegetables (AIVs) or African underutilized Vegetables (AUVs) or African Leafy Vegetables (ALVs)," "Processing," "postharvest management or postharvest technologies," "nutrition sensitive," "value chains," and "food systems." The literature was obtained through the Elsevier's Scopus, Web of Science, Google scholar, Science Direct and, Emerald Springer online search engines. As our general question is to evaluate how postharvest management and processing of AIVs can contribute to transformation of food systems by enhancing nutrition sensitivity, each section of the review provides an appraisal of current published results on the topic, giving an overview of the current knowledge, the gaps, and provides a rationale and directions for future interventions.

3. Results and discussion

3.1. Relevance of African indigenous vegetables toward nutrition

In the context of rural farming communities where AIVs are predominantly produced, they can play a key role in promoting nutrition as well as resilience and adaptability of the entire local food systems to changing climatic conditions. Being minimally reliant on external input for their production (Weinberger et al., 2011), highly dense in nutrient and health promoting properties (Neugart et al., 2017) as well as high adaptability to climate change (van Zonneveld et al., 2021) are key characteristics that underline the relevance of AIVs toward promoting nutrition sensitive value chains. Evidence from existing studies allude to these facts. For

example, Francis et al. (2017) emphasized the need for a shift toward strategies that place an equal emphasis on human nutrition and health, as well as environmental sustainability in order to provide food and nutrition security. While, Cogill (2015), Neugart et al. (2017), and Mwanga et al. (2020) extensively reported the nutritional and health role of AIVs as essential sources of micronutrients and a relatively cheap source of plant based protein, especially for the low income rural and peri urban households, in addition to essential minerals and vitamins necessary for maintaining human health and strengthening resistance to disease and infection. AIVs have been reported to contribute up to 11–12% to the total daily dietary protein consumption while exotic vegetables contributed 4% (Gockowski et al., 2003; Mwanga et al., 2020). In Kenya, the dietary protein contribution of AIVs was found to be higher in rural areas (10% higher) than in peri-urban areas (Mwanga et al., 2020). Compared to some exotic vegetables, some AIVs have been reported to be superior sources of protein and micronutrients (Nyadanu and Lowor, 2015). Additionally, AIVs support a large number of small-scale farms with women significantly involved in all segments along the entire value chain in urban and peri-urban areas (Otieno et al., 2019). This is in addition to low capital requirements for entry into their value chains, that enables even the poorest households to participate (Weinberger et al., 2011).

Essentially, AIVs may offer new opportunities for development of nutrition sensitive, resilient and sustainable food systems and there is growing evidence toward this potential as aforementioned and as summarized in Table 1 below. They can widen the sources of health promoting compounds required for human health, increase diversity and quality of diets, are uniquely adapted to local environments and have potential to create local market niches in rural and peri-urban economies (Mabhaudhi et al., 2019). Additionally, they are important in terms of climate change, given their adaptive features that promote growth under marginal conditions, and the low cost of fertilizers and pesticides required in their production. Hence, promoting their cultivation aligns with sustainable agricultural practices (Shayanowako et al., 2021). All the above characteristics can drive better nutritional outcomes for communities as well as contributing to nutrition-sensitive and resilient local food systems.

3.2. Current knowledge of postharvest management and processing of AIVs

3.2.1. Current practices in postharvest management of AIVs and implications for sustainable and nutrition-sensitive value chains

The objectives of postharvest management are majorly: (i) to minimize food loss and waste, (ii) to preserve nutritional quality and safety of food, and (iii) to improve storability and prolong shelf life of products (Matrose et al., 2021). As such, the key components in postharvest management of fresh vegetables include; appropriate harvest time, temperature control, transportation, handling and postharvest treatments, preservation, packaging, and storage. Additionally, application of targeted postharvest treatments and use of preservation technologies also significantly contribute to food safety, reduce product physiological deterioration and prolong the shelf life and quality of AIVs (Deng et al., 2020).

Available research indicates that postharvest temperature control is important for reducing the physiological activity of fresh produce and thus preventing deterioration and product decay (Duan et al., 2020). However, current studies on AIVs show that cooling is predominantly conducted through keeping fresh produce under shades, sprinkling water on fresh produce, and covering with fresh leaves or bundling products to prevent transpiration losses (Sipho and Tilahun, 2020). However, these are measures that cannot adequately keep AIVs safe and fresh. Cold storage which reduces respiration, transpiration, and leaf senescence of fresh vegetables is largely not available at the producer, wholesale, and transporter stages of the chain, with refrigerated storage only applied in the urban retail supermarkets (Makule et al., 2022). This is mainly attributed to AIVs being predominantly produced in rural areas, by resource-constrained smallholder farmers, with limited access to electricity and cold storage facilities. In view of these constraints, it is recommended that cold storage for AIV value chains should be based on energy-efficient and cost-effective technologies. Integration of such emerging cost-efficient, postharvest, cold chain technologies can have many beneficial effects in terms of maintaining the nutritional value of AIVs along the chain. For example, evaporative cold storage has been found to enhance vitamin C retention in amaranth (Ambuko et al., 2017), while Sorour et al. (2022) showed that refrigerated storage maintained the mineral contents of spinach and jute mallow. Currently, AIVs are mostly sold without packaging, but rather simply graded and tied in bundles (Govindasamy et al., 2020). However, particularly when cooling facilities are not available or affordable, film packaging is known to be a good alternative to reduce deterioration of AIVs (Gogo et al., 2017), which needs to be explored in more detail. These observations clearly show that current postharvest management practices are limited and so lessen the possibility to establish sustainable and nutrition-sensitive value chains of AIVs.

3.2.2. Contextual issues in postharvest management of AIVs from a practical perspective

A number of constraints that affect postharvest management of AIVs have been documented. For instance, most rural areas lack electricity (Muhumuza et al., 2018), which is vital for processes such as refrigeration. The road infrastructure is poorly developed in most of these rural areas (Imathiu, 2021), which affects transportation and timely delivery of fresh produce to the market. There is also inadequate investment in postharvest and processing technologies (Makule et al., 2022), which limits availability and access to such technologies. These constraints are majorly attributed to the context under which AIVs are produced, being characterized by predominantly rural and peri-urban smallholder farmers, poorly organized marketing, middlemen (retailers) being major players, and reliance on non-specialized public transportation (Gogo et al., 2018b).

The aforementioned contextual realities therefore require that technologies promoted within the AIV value chains should be accessible, affordable, and sustainable. As such, research should

TABLE 1 Evidence of relevance of AIVs to nutrition and health.

Dimension of relevance	Key published findings	References
Dietary diversity	They contribute to increased diversity and quality of diets by supplying alternative plant sourced proteins, vitamins minerals, and carbohydrates.	Cogill, 2015
	They offer potential for diversifying dietary quality of other foods through food-to-food fortification.	Odunlade et al., 2017
Plant based proteins, vitamins and minerals	AIVs are rich in micronutrients such as iron (Fe), zinc (Zn), calcium (Ca), magnesium (mg). By providing a cheaper source of many essential vitamins and minerals, they can contribute to reducing micronutrient deficiencies.	Aworh, 2018
	They can provide significantly higher sources of proteins, carbohydrates, dietary fibers, potassium, calcium, magnesium, phosphorus, Vitamin A, Vitamin C and Vitamin E compared to some of their exotic counterparts.	Nyadanu and Lowor, 2015
	They contain substantial amounts of proteins that can be used in food formulations to replace animal-based proteins in human diets.	Rivero Meza et al., 2023
Household incomes	AIVs provide a source of livelihood, majorly to women farmers in rural and peri-urban communities.	Dinssa et al., 2016
	They contribute to diversification and stability of household incomes, creating local niche markets.	Krause et al., 2019
Climate change adaptation	AIVs are resilient with adaptive features that enable production even under marginal conditions.	Mabhaudhi et al., 2019
Human health and Non-communicable diseases (NCDs)	They are good sources of essential secondary metabolites and other health promoting compounds such as antioxidants, carotenoids, dietary fibers etc. These are critical for protection against common NCDs such as heart disease, and diabetes.	Neugart et al., 2017
	Some protein extracts from amaranth have anti-microbial, anti-inflammatory, antidiabetic, anti-hypertensive and anti-atherosclerotic activity.	Rivero Meza et al., 2023

provide alternatives that; (i) are less power intensive, (ii) are less expensive, and (iii) ensure safety and preserve nutritional quality. Examples of emerging technologies that could be suitable for AIV value chain contexts include, among others, evaporative cooling technologies, sustainable packaging materials, controlled drying for extended shelf life, solar coolers, and use of cold transportation systems (Ambuko et al., 2017; Cheptoo et al., 2020; Ameta et al., 2021; Amwoka et al., 2021; Mostafa et al., 2022). Additionally, networking among AIV value chain actors in terms of exchanging knowledge, demands, and requirements for quality and loss reduction may also contribute toward a more nutrition-sensitive value chain.

3.2.3. Current processing technologies for AIV preservation by smallholder farmers

Processing methods commonly used to add value to AIVs include drying, blanching, canning, boiling, fermentation, malting, milling, popping, roasting, steaming, and wet milling, depending on available processing equipment and whether the raw materials are leaves or seeds (Mazike et al., 2022). The most common method for processing AIVs is drying. Leafy vegetables which have been dehydrated by drying are light and can easily be re-converted into fresh-like form for consumption throughout the year (Singh and Sagar, 2010).

Open-air sun drying is the most common method in tropical countries, due to its affordability, especially for smallholder farmers in rural areas. But it has many drawbacks commercially because it is difficult to manage large quantities to achieve homogenous quality and food safety (Managa et al., 2020b). This is because the sun drying process greatly relies on ambient conditions, with produce very prone to contamination by dust, rain, wind, and pests (El Hage et al., 2018). The resultant low-quality products and nutrient losses compromise the nutritional and market value of dried AIVs. Solar drying technology has a greater advantage than direct sun drying and leads to better product quality and retention of nutrients, but requires more capital investment in the equipment (Yegon et al., 2021). Boiling and blanching leafy AIVs is often done prior to drying. Boiling is used by indigenous people to reduce or eliminate the bitterness of some vegetables, thus improving flavor and taste (Oulai et al., 2015). Blanching can be applied using steam or water. Blanching leafy AIVs improves color and carotene retention due to inactivation of enzymes, but it causes losses of vitamin C (Mkandawire and Masamba, 2014; Njoroge et al., 2015). Blanching green leafy vegetables in water containing potassium metabisulphite has been shown to effect better retention of vitamin C than blanching in water containing sodium carbonate or sodium chloride (Ranganathan et al., 2017). Managa et al. (2020a) further demonstrated that steam blanching and lemon juice addition retained more phenolic metabolites in African nightshade in comparison to untreated products. Fermentation of AIVs increases their storability duration, palatability, aroma, and texture and it increases the availability of proteins and vitamins such as folate (Muchoki et al., 2007; Wafula et al., 2016; Misci et al., 2021). Moreover, fermentation of AIVs followed by drying has been reported to result in lowered postharvest losses, improved taste, maintained quality, and increased product safety (Wafula et al., 2016). Traditionally, smallholder farmers have practiced natural fermentation but current studies have involved the use of starter cultures in cowpea leaves (Wafula et al., 2016). Studies have also shown successful fermentation of African kale (*Brassica carinata*) using lactic acid starter strains (Oguntoyinbo et al., 2016). Furthermore, canning technologies have been used as a preservative measure for many vegetables and can also be

applied to AIVs to give consumers access to a wider choice of convenient, shelf-stable, value-added, and modern products that appeal to urban dwellers (Onyeorizi et al., 2017; Sigaqa et al., 2017). However, canning is capital intensive and would require high initial investment, hence it remains unaffordable for small-scale farmers and processors.

The value-added products from AIVs include dried vegetables, canned vegetables, fermented vegetables, and dried leaf powder that can be used for fortifying various meals or added into products such as biscuits, and pasta for nutritional enhancement (Mazike et al., 2022).

3.2.4. Adoption of AIV postharvest and processing technologies

In SSA, there is a double challenge of low level of investment in postharvest and processing technologies (Owade et al., 2020; Sugri et al., 2021) and high barriers to adoption (Stathers et al., 2020). Typically, the current technologies adopted and used by smallholder AIV farmers are identified as traditional in nature (Mazike et al., 2022). Moreover, there is generally slow progress in upgrading traditional food processing and preservation techniques in Sub-Saharan Africa (Aworh, 2008). The reasons for the limited uptake of such technologies are linked to; (i) lack of adequate knowledge, (ii) poor education and extension for dissemination, and (iii) economic, social, and cultural limitation (Shayanowako et al., 2021). For instance, solar-dried AIVs are of better quality in terms of nutritional content, hygiene, as well as appearance, color, and taste than open sun–dried AIVs. However, studies show that the solar-dried AIVs are still not widely known to many households, and related knowledge is relatively low compared to open sun drying (Kessy et al., 2018; Yegon et al., 2021).

Traditional food processing aims to maintain the supply of healthy, nutritious food throughout the year, especially in times of scarcity while commercial processing seeks to generate income for the producer and seller (Bokelmann et al., 2022). Small-scale food industries, involving modest mechanization of traditional methods, with possibilities for replication in rural areas where the raw materials are produced, offer better prospects for success than large, fully mechanized processing plants (Uzoejinwa et al., 2016). In addition, small-scale plants have the advantage of being able to match processing capacity with raw material supply and are, therefore, less adversely affected by raw material shortages than large-scale food industries. Omulo (2016) found that value addition of traditional vegetables and establishment of an amaranth grain milling plant in western Kenya resulted in women farmers marketing their produce better, with significantly increased incomes and subsequent purchasing power.

3.3. Prospects for transformation of nutrition-sensitive AIV value chains

3.3.1. Prospects for transformation of nutrition-sensitive AIV value chains through improved postharvest management

In developing countries, food losses occasioned by poor postharvest management contribute to high economic and nutritional losses (Yahia et al., 2019). As such, postharvest and processing challenges are key bottlenecks to achieving nutrition-sensitive fruit and vegetable value chains (Keding et al., 2013). These observations imply that interventions that improve postharvest management along the value chain would contribute significantly toward food systems transformation, and improving food and nutrition security. Key interventions that can be undertaken toward enhancing nutrition-sensitive AIV value chains through appropriate postharvest management include (i) postharvest temperature control, i.e., appropriate cold chain along the supply chain and storage conditions, (ii) postharvest treatments for sanitation and improving nutritional and health-promoting product properties, and (iii) film packaging (Figure 1).

Essentially, integration of cold chains along the value chain of AIVs is expected to minimize produce losses and enhance

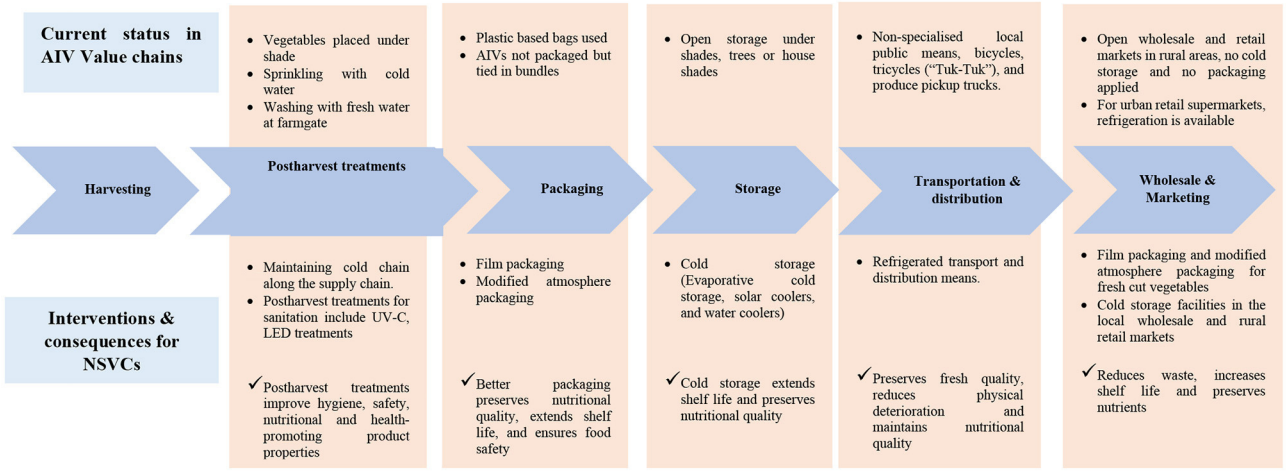

FIGURE 1
Possible intervention points for improved postharvest management in a nutrition-sensitive AIV value chain.

nutritional preservation. For instance, (i) use of passive evaporative cooling systems like charcoal and brick coolers, which have high energy efficiency at low costs (Ambuko et al., 2017); (ii) refrigerated cold rooms and transport means, which may be effective but relatively expensive (Maiorino et al., 2021); (iii) forced-air cooling, the effectiveness of which may be limited by the air flow configuration used, and thus may increase cost (Makule et al., 2022); and (iv) water cooling, including mobile coolers that may be immersion-type, conveyor coolers, and shower-type batch coolers, the costs of which are generally low, but with high energy efficiency (Elansari et al., 2019). These opportunities and advantages notwithstanding, in most developing countries in SSA there is insufficient infrastructure and skills to support the development and integration of low-cost cold chain technologies along agricultural chains (Sipho and Tilahun, 2020), particularly in rural and peri-urban areas where AIVs are predominantly produced.

On the other hand, some postharvest treatments have been shown to have nutritionally beneficial effects on vegetables. For example, Gogo et al. (2018a), showed that postharvest application of UV-C increases shelf life and promotes the nutritional and health-benefiting values of amaranth such as enhanced antioxidant capacity and induced accumulation of flavonoids and phenolics. Similarly, Jin et al. (2021) found a positive influence of light (LED) treatment on shelf life and antioxidant activity of freshly cut amaranth. Even though postharvest treatments of leafy AIVs have not yet been widely applied, research indicates that their application would enhance retention of nutritional value along the chain. It should be further noted that the application of these treatments at large scale or industrial levels is also yet to be demonstrated.

3.3.2. Prospects for transformation of nutrition-sensitive AIV value chains through improved processing and preservation

Limited product diversification, innovation, and value addition in the AIV value chain (Maseko et al., 2018), resulting in a lack of indigenous vegetables in modern commercialized and industrialized markets, has hindered the potential to make them more attractive, convenient, and accessible. Whereas preservation solves the problem of perishability of AIVs, it does not satisfy the needs of consumers who prefer consumption of freshly harvested AIVs. Therefore ways of ensuring that these consumers' needs are met need to be explored (Imathiu, 2021). Further research needs to identify the best methods for maintaining nutrients but at the same time diversifying value-added products using advanced food-processing technologies such as rolling, canning, extrusion, malting, and flaking (Mazike et al., 2022). Refractive window drying—which is used to dry heat-sensitive fresh produce and preserves their nutrients, color, flavor, aroma, and bioactive compounds, as well as the sensory quality—offers the possibility of high-value products from AIVs (Mahanti et al., 2021; Nyaguti et al., 2021). It should be noted that there is still a need to make investments in relatively low-cost, value-addition machinery and in facilitation of the requisite regulatory certification for processors in order to increase the competitive advantage of AIV-based products. Maseko et al. (2018) proposed the broadening of AIV consumption habits by promoting the use of developed vegetable products as snacks and accompaniments to beverages, rather than limiting them to accompanying sauces. Additionally, efforts should be channeled to informing consumers about the benefits of AIVs in order to create demand; to supporting farmers and processors by linking them with markets to ensure supply; and to providing supportive policies to facilitate the strategic positioning of AIVs (Shayanowako et al., 2021).

4. Conclusion

Current postharvest and processing technologies and practices along AIV value chains are limited, making AIVs highly susceptible to quantitative and nutritional losses. However, due to their high nutritional value, they are still very important to a nutrition-sensitive value chain. Transformation of the chain would require development and innovative adaptation of postharvest and processing technologies that are well-suited to the resource and socioeconomic context of AIV value chain actors, essentially considering limitations such as infrastructure, electricity supply, and economic feasibility. Additionally, the limited processing reveals an opportunity for product diversification through improved processing methods. These interventions would ultimately transform the AIV value chain by reducing food loss and food waste, creating more value for the value chain actors, and thus strengthening the chain's capacity to be nutrition-sensitive and to promote rural development. The major limitation of this study however is that we only considered literature published between 2007 and 2022, and only publications in English language were considered.

Author contributions

SE and RB wrote the background relevance of AIVs toward nutrition, conclusion, and abstract. SE wrote the methodology, current practices in postharvest management of AIVs, contextual issues in postharvest management of AIVs, and prospects for transformation of nutrition-sensitive AIV value chains through improved postharvest management. RB wrote section current processing technologies for AIV preservation and prospects for transformation of nutrition-sensitive AIV value chains through improved processing and preservation. AMO, DN, DM, and SH-K revised and edited the whole manuscript. All authors contributed to planning the contents of the manuscript and approved the final version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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EDITED BY
Walter Odongo,
Gulu University, Uganda

REVIEWED BY
Achille Assogbadjo,
University of Abomey-Calavi, Benin
Solomon Olum,
Gulu University, Uganda

*CORRESPONDENCE
Hassabelrasoul A. M. Saeed
✉ hasabohaaj@gmail.com

†PRESENT ADDRESS
Hassabelrasoul A. M. Saeed,
Department of Natural Environment,
Faculty of Forestry,
Technical University in Zvolen,
Zvolen, Slovakia

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Consumers behavior, attitudes, and beliefs regarding baobab (*Adansonia digitata* L.) fruit and pulp consumption in Sudan

Hassabelrasoul A. M. Saeed[1]*†, Yahia Omar Adam[1], Emmanuel Donkor[2] and Dagmar Mithöfer[2,3]

[1]Department of Forest Management, Faculty of Forestry, University of Khartoum, Khartoum Bahri, Sudan, [2]Agrifood Chain Management Group, Albrecht Daniel Thaer-Institute of Agricultural and Horticultural Sciences, Humboldt-Universität zu Berlin, Berlin, Germany, [3]Faculty of Life Sciences, Hochschule Rhein-Waal, Kleve, Germany

There are growing number of empirical studies on the baobab value chain in Sub-Saharan Africa. Most studies focus on nutritional composition, traditional uses, the distribution of baobab trees, and collection. However, there are few studies on the marketing of baobab fruit pulp, especially on consumer behavior, attitudes, and beliefs regarding baobab fruit pulp. In this context, our study aims to explore consumer behavior, attitudes and beliefs regarding baobab fruit pulp. We also evaluate the market development potential of baobab fruit pulp in selected markets in El Obeid and Khartoum in Sudan. The study employs a mixed methods approach that includes a survey (*N*=499), focus group discussion (*N*=16), stakeholder interviews (*N*=2), and a SWOT analysis. The study shows that the consumption of baobab fruit pulp is common among Sudanese consumers. Consumers also show strong positive attitudes and beliefs, as well as social support for baobab consumption. Nutritional and health benefits tend to drive consumer interest in baobab fruit pulp. The study also identified high demand, export opportunities, and extraction of ingredients from baobab as opportunities to develop baobab markets. However, a lack of quality control, regulations, poor distribution, and insufficient fruit supply may limit exploration of these opportunities. Therefore, it is crucial to raise knowledge of the nutritional and functional properties of baobab fruit, as well as its ability to fight health-related diseases, to further develop local markets. Processors must also improve the quality and safety of their goods. Policymakers must also create a regulatory structure that supports Sudan's baobab value chain.

KEYWORDS

baobab value chain, consumer behavior, Sudan, local food systems, marketing opportunities, SWOT analysis, mixed methods

1. Introduction

Achieving the Sustainability Development Goals (SDGs) of "No Poverty" (SDG 1) and "Zero Hunger" (SDG 2) is a key policy priority for many countries in Sub-Saharan Africa. However, food insecurity and malnutrition are rising in many countries in Sub-Saharan. For instance, 34% (15 million people) of the Sudanese population is currently food insecure and this is expected to rise to 39% by the end of 2022 (World Food Programme, 2022). This is mainly driven by the climate-conflict nexus, characterized by political instability and climate shocks. This has been

exacerbated by global crises such as COVID-19 and the war in Ukraine (World Food Programme, 2022).

In Africa, urbanization is one factor driving food system transformation (de Bruin et al., 2021). In Sudan, rapid urbanization has been observed in the last three decades due to conflict, drought, and desertification, which force rural people to leave rural area (Young and Jacobsen, 2013). As a result, over 35% of the population now lives in urban areas (World Development Indicators: Urbanization, 2021). Many of the urban poor face challenges in accessing land and developing viable livelihood strategies. Urbanization further changes the food system such that an increasing share of the population depends on purchasing food (Babiker, 1982; Young and Jacobsen, 2013). In Sudan, the conflict in Darfur led to a large population flow from rural to urban areas, where security services are available. However, this migration pattern resulted in changes in food supply and availability, contributing to a rise in local food prices in urban areas with negative consequences for urban consumers (Alix-Garcia et al., 2012).

Sudan is characterized by high variability in agro-climatic conditions, which means that a wide range of different crops can be grown throughout the year (El-Shishiny and Ghabbour, 1989; Bashir et al., 2014). Efforts have been made to strengthen supply chains for major crops such as vegetables, grains, cereals, and fruits to improve food and nutrition security. This is because many people in Sudan depend on the local food systems for their livelihoods with little dependence on food imports. Agriculture is rainfed; hence, even little variability in rainfall pattern tends to adversely affect food supply in the country. For instance, fruits and vegetables in the southern and western states, in areas with high rainfall, are usually irrigated or grown with rainwater on a small-scale (Marzin et al., 2016).

To increase the resilience of the local food systems in Sudan, diversification into non-forest plant species that are more resilient to climate change and variability is an important option. Non-forest plant species such as baobab offer income-generating opportunities for many people in Sudan, contributing to food security (Aworh, 2015). The baobab tree (*Adansonia digitata* L.) is a multi-use, widely-used species, rich in nutrients in its leaves and fruits, and used daily by local populations in numerous African countries for food, medicines, and other purposes (Yazzie et al., 1994; De Caluwé et al., 2009; Gadour et al., 2017; Muthai et al., 2017). Pulp, seeds, leaves, root tuber, and bark have been studied for their properties and have been shown to have potential for pharmaceutical uses (Lisao et al., 2017). Baobab pulp contains high levels of vitamin C (Chadare et al., 2008), calcium (Osman, 2004), and antioxidants (Salih and Yahia, 2015). Baobab pulp is naturally dry and a purely organic food as it is collected from trees from the wild without the use of external inputs. It is a dietary source of fiber, potassium, calcium, magnesium, iron, and zinc (Muthai et al., 2017). Numerous researchers in different African countries have emphasized this indigenous fruit tree as a significance species for domestication and expanded use (Gebauer et al., 2016).

In Sudan, utilization of wild fruit mostly relates to environment crises such as drought, desertification, food shortages, and starvation, and particularly to the ongoing war in Kordufan and Darfur (Dirar, 1993; Salih and Ali, 2014). Baobab fruits and pulp play an important role in Sudan's food culture, and are consumed daily by local people, mostly as snacks without need of further processing, as beverages or prepared within porridges (Salih and Ali, 2014). Unripe baobab fruits are boiled and used as salad and the dry fruit pulp is either eaten fresh or dissolved in water or milk as juices, to serve tourists and hostels (Al Faki Adam, 2019). Baobab fruit pulp flour is used as a starter in the fermentation of the sorghum flour used for *Kisra* (pancake-like fermented flat bread) preparation (Makawi et al., 2019).

The collection of non-timber forest products is well-known in Sudan. Among non-timber forest products gathered and commercialized are *Adansonia digitata* Linn., *Balanites aegyptiaca* Del., *Tamarindus indica*, *Ziziphus spina-christi* (L.) Desf, *Grewia tenax* (Forsk) and Fiori (Adam et al., 2013). The baobab market chain in Sudan begins with the collection and gathering of baobab fruits in remote areas by local people (Elnasri, 2019). Baobab collection usually happens in the dry season, when farmers have limited agricultural activities and look for alternative sources of income (Adam, 2017). Collectors sell baobab fruits to village traders, who then sell them to wholesalers. In some cases, collectors travel to nearby villages or to the capital, Khartoum, to sell their products.

The majority of existing studies on baobab have focused on the analysis of nutritional composition (Osman, 2004; Chadare et al., 2008; De Caluwé et al., 2009; Gadour et al., 2017; Lisao et al., 2017; Muthai et al., 2017), while studies on collection and marketing are limited. For instance, Adam et al. (2013) analyzed the factors influencing the contribution of non-timber forest product (NTFP) livelihood strategies to household income in Sudan and found that income from sales of baobab fruits was influenced by internal and external factors. Kaimba et al. (2020) analyzed factors influencing baobab collectors' choice of marketing channels in Kenya and reported that human capital and transactional and institutional factors affect collectors' choice of marketing channel. Kaimba et al. (2021) investigated baobab pulp's response to price and non-price incentives in Kenya and found that baobab pulp supply and profits responded positively to price incentives but negatively to labor, transport, and packaging input costs. Meinhold et al. (2022) investigated how baobab fruit products overcame challenges encountered by most NTFPs in accessing global markets. They found that the rising demand for natural, healthy foods, increasing knowledge and appreciation for indigenous products, and rising numbers of entrepreneurs and development organizations were the main factors. Meinhold and Darr (2022) evaluated the implications of commercialization of baobab fruits on quality and supply chain organization in Malawi. They reported that the baobab supply chain has elongated with different actors participating in the chains: baobab collectors and traders collecting baobab fruits at source, microenterprises processing baobab fruits into ice-lollies for informal markets, or more formal processors targeting retail markets. However, baobab value chains in Sudan have received limited research and policy attention; hence, there is limited information on consumer behavior and attitudes towards processed baobab products in Sudan. Adam (2017) evaluated consumers' preferences and factors influencing demand for baobab fruits in Elobeid and Khartoum markets in Sudan using descriptive analysis and found that there is demand for baobab fruit and its secondary products. Adam (2017) also found nutritional value (vitamins) of the baobab fruits to be the main factor driving the demand. However, this study did not evaluate development potential and threats for marketing of baobab fruit/pulp markets. Hence, there is a lack of evidence in this respect.

In this context, this study aims to address the following research questions:

i. What are consumer behavior, attitudes, and beliefs regarding processed baobab fruits in Sudan?
ii. What are the strengths, opportunities, weaknesses, and threats to the market development of baobab fruits/pulp in Sudan?

By answering these research questions, this paper contributes to the existing literature on baobab in the following ways. First, we provide exploratory findings on consumer behavior, attitudes, and beliefs regarding processed baobab fruits/pulp, where consumer behavior is conceptualized as frequency of baobab purchase and place of purchase. We also provide findings on stakeholders' perspectives on strengths, opportunities, weaknesses, and threats to the development potential of the baobab markets in Sudan. This also complements the study by Adam (2017), which only focused on consumer preference without insights into opportunities and threats for market development of baobab. Our paper also complements previous studies (Kaimba et al., 2020, 2021) that have mainly focused on the marketing of baobab from collectors' perspectives and those (Meinhold et al., 2022; Meinhold and Darr, 2022) that have focused on the development of the baobab supply chain with little focus on consumer behavior. To gain better insights into the research questions, we use a mixed methods research approach.

Moreover, the findings of the study will provide stakeholders and policymakers with insights into threats and weaknesses to be overcome, as well as marketing opportunities and strengths that can be exploited in developing the baobab value chain in Sudan. Identifying marketing opportunities in the baobab value chain could attract investors to the sector. The development of the sector can contribute to improving food and nutrition security in Sudan, as many people derive their livelihoods from this sector. Development and marketing of innovative food products starts with consumers (Bogue and Sorenson, 2009; Bleiel, 2010). Therefore, a better understanding of consumer behavior, attitudes, and beliefs provides good guidance for the design of a long-term marketing strategy for baobab fruit and pulp products. A consumer-driven approach is an innovative strategy to advance functional food marketing. It is crucial to gain knowledge of consumer interests and to identify their behavior, needs, and desires in order to invest appropriately in functional benefits (Granato et al., 2020). Such information can help in formulating baobab fruit and pulp marketing and development strategies in Sudan.

2. Materials and methods

2.1. Research design and source of data

We conducted an exploratory mixed methods study to address the research questions. Both quantitative and qualitative studies were conducted concurrently in selected markets in two cities in Sudan. One rural market was selected from El Obeid and four markets from Khartoum, a capital city of Sudan. El Obeid (13° 18 N and 30° 22 E) is in the dry zone of central Sudan, North Kordofan State, and is approximately 600 km from the capital Khartoum. The population is about 340,940. The city is characterized by a thriving market for gum Arabic, the most important non-timber forest product in Sudan. Khartoum (15° 33 N and 32° 32 E) is the capital of the country with total population of 4,286,000. The selected cities provide a wide contrast in terms of their socio-economic and other demographics factors. Both cities are characterized by thriving markets for non-timber forest products and baobab fruit and pulp is frequency traded and widely consumed at both sites.

We used a non-probability convenience sampling procedure to collect quantitative data for this study. We selected 449 consumers, comprising 233 from four urban markets in Khartoum and 216 from the rural market in El Obeid. The two locations for markets were selected purposively as they: (i) are identified as the most important for non-timber forest products in Sudan; and (ii) constituted a large portion of baobab fruits and pulp marketing in Sudan. In both sites, respondents were sampled from traditional open markets, small supermarkets, and other outlets when they were in the process of purchasing baobab fruits and pulp. A survey questionnaire was used to solicit relevant information from the selected respondents. The questionnaire was structured into two sections. The first section captured information on demographic characteristics (gender, age, household size, education level, main occupation, and household income) of the respondents. The second section included items to measure key concepts such as beliefs, attitudes, behavior, and preferences for processed baobab pulp. Behavioral items captured the place of purchase, purchase frequency, and quantities. The questionnaire was first pretested on 22 people and necessary adjustments were made.

We also conducted a qualitative study to complement the quantitative study by providing additional information that could not have been collected using the quantitative study alone. In the qualitative study, we conducted two focus group discussions (see Appendix Table A1 for the interview guide for the focus group discussion) to gain deeper insights into an overview of consumers' general attitudes and consumption behavior on baobab fruit and pulp consumption. Two focus group discussions were carried out in El Obeid and Khartoum, with nine participants in El Obeid, and seven in Khartoum. The focus group discussions were conducted alongside a consumer survey in order to validate the survey findings. The focus groups included female and male participants, aged 18 and above. The participants were recruited according to their experience with baobab fruit and pulp consumption, and ensuring diversity of their age and gender. In addition, we conducted stakeholder interviews using semi-structured interviews (see Appendix Table A2 for the stakeholder interview guide). Field notes were also taken during field visits in the study areas.

The stakeholders included representatives from companies based in Khartoum that process indigenous fruit pulp and juice fruits (e.g., *Tamarindus indica* and *Adansonia digitata*), and representatives from relevant fruit/pulp juice industries in Khartoum. Only two interviews were conducted; two planned interviews did not take place due respondents' fears about taxes. The interview covered information about market trends in the baobab fruit pulp sector; the current position of baobab fruits, pulp, and juice in the market; and perceived prospects and problems regarding the current and further development of the business.

2.2. Measurement of concepts

The key concepts in the study include consumer attitudes, beliefs towards product attributes, social influence, product familiarity, and behavior. We adapted and used the general attitude scale from Sabbe

TABLE 1 Scale of general attitudes, product attributes, and social influence.

Concepts	Items	Scale
General attitudes	I feel good/bad when I eat the baobab fruit pulp.	1 = bad, 2 = slightly bad, 3 = neither good nor bad, 4 = slightly good, 5 = good
	I feel satisfied/unsatisfied when I drink the baobab fruit juice.	1 = unsatisfied, 2 = slightly unsatisfied, 3 = neither satisfied nor unsatisfied, 4 = slightly satisfied, 5 = satisfied
	I feel pleasant/unpleasant when I eat the baobab fruit pulp.	1 = unpleasant, 2 = slightly unpleasant, 3 = neither pleasant nor unpleasant, 4 = slightly pleasant, 5 = pleasant
	I feel happy/unhappy when I eat the baobab fruit pulp.	1 = unhappy, 2 = slightly unhappy, 3 = happy nor unhappy, 4 = slightly happy, 5 = happy
	I feel well/awful when I eat the baobab fruit pulp.	1 = awful, 2 = slightly awful, 3 = neither well nor awful, 4 = slightly well, 5 = well
	I feel positive/negative when I eat the baobab fruit pulp	1 = negative, 2 = slightly negative, 3 = neither positive nor negative, 4 = slightly positive, 5 = positive
Beliefs of product attributes	I consider the baobab fruits pulp cheap/expensive	1 = expensive, 2 = slightly expensive, 3 = neither expensive nor cheap, 4 = slightly cheap, 5 = cheap
	I believe that baobab fruit pulp is available/not available.	1 = unavailable, 2 = slightly unavailable, 3 = neither available nor unavailable, 4 = slightly available, 5 = available
	I think that the baobab fruit pulp is ethical/not ethical.	1 = unethical, 2 = slightly unethical, 3 = neither unethical nor ethical, 4 = slightly ethical, 5 = ethical
	I consider that the baobab fruits pulp is safe/not safe	1 = unsafe, 2 = slightly unsafe, 3 = neither safe nor unsafe, 4 = slightly safe, 5 = safe
	I believe that baobab fruit pulp is nutritious/not nutritious.	1 = not nutritious, 2 = slightly not nutritious, 3 = neither not nutritious nor nutritious, 4 = slightly nutritious, 5 = nutritious
	I believe that baobab fruit pulp and juice has good taste/bad taste	1 = bad taste, 2 = slightly bad taste, 3 = neither bad nor good taste, 4 = slightly good taste, 5 = good taste
	I believe that baobab fruit pulp has good quality/bad quality.	1 = bad quality, 2 = slightly bad quality, 3 = neither bad nor good quality, 4 = slightly good quality, 5 = good quality
	I believe that baobab fruit pulp is sustainable/not sustainable.	1 = unsustainable, 2 = slightly unsustainable, 3 = neither unsustainable nor sustainable, 4 = slightly sustainable, 5 = sustainable
	I believe that baobab fruit pulp is healthy/not healthy.	1 = unhealthy, 2 = slightly unhealthy, 3 = neither unhealthy nor healthy, 4 = slightly healthy, 5 = healthy
	I believe that baobab fruit pulp is attractive/not attractive	1 = unattractive, 2 = slightly unattractive, 3 = neither unattractive nor attractive, 4 = slightly attractive, 5 = attractive
	I believe that baobab fruit pulp is specially/not specially.	1 = not speci1ally, 2 = slightly not specially, 3 = neither not specially nor specially, 4 = slightly specially, 5 = specially
Social influence	To what extent does your husband/wife influence your decision to eat baobab fruit?	1 = inhibiting factor, 2 = slightly inhibiting factor, 3 = neither inhibiting nor stimulating factor, 4 = slightly stimulating factor, 5 = stimulating factor
	To what extent do your children influence your decision to eat baobab fruit products?	1 = inhibiting factor, 2 = slightly inhibiting factor, 3 = neither inhibiting nor stimulating factor, 4 = slightly stimulating factor, 5 = stimulating factor
	To what extent does your family influence your decision to eat baobab fruit products?	1 = inhibiting factor, 2 = slightly inhibiting factor, 3 = neither inhibiting nor stimulating factor, 4 = slightly stimulating factor, 5 = stimulating factor
	To what extent do your friends influence your decision to eat baobab fruit products?	1 = inhibiting factor, 2 = slightly inhibiting factor, 3 = neither inhibiting nor stimulating factor, 4 = slightly stimulating factor, 5 = stimulating factor
	To what extent do your colleagues at work influence your decision to eat baobab fruit?	1 = inhibiting factor, 2 = slightly inhibiting factor, 3 = neither inhibiting nor stimulating factor, 4 = slightly stimulating factor, 5 = stimulating factor

Adapted from Sabbe et al. (2008).

et al. (2008), which is based on six items, to evaluate consumer attitudes towards processed pulp. Based on Sabbe et al. (2008), we also adapted and modified belief and social influence to assess consumer beliefs toward attributes of processed baobab products, as well as social influence regarding the consumption of processed baobab products. The measurement of the concepts is summarized in Table 1.

We further complemented the consumer perspective with a strength, weaknesses, opportunities, and threats (SWOT) analysis from the business perspective. SWOT analysis is a strategic planning method used to systematically evaluate the external opportunities and threats and the internal strengths and weaknesses of a project or business venture (Bernroider, 2002). The SWOT analysis was done in three sequential stages. First, the external market environment (i.e., opportunities and

threats) was evaluated using information gathered from the literature and consultations with stakeholders involved in the national baobab fruit/pulp industry in Sudan. Second, the internal strengths and weaknesses of baobab fruit/pulp and its respective production and supply chain were identified from a combination of observations during field visits and findings from a business stakeholder study on baobab fruits/pulp, which was performed both in El Obeid and Khartoum. Third, the collected information was synthesized in a SWOT-matrix and evaluated to determine the extent to which the identified facts constitute opportunities, threats, strengths, and weaknesses for the use of baobab fruits and pulp in the national baobab products industry. This analysis finally resulted in the formulation of key attention points for strategy development of baobab fruit/pulp products.

2.3. Data analysis

We proceeded with data analysis by first analyzing the quantitative data. We used descriptive statistics such as tables and graphs to analyze the quantitative data. Inferential statistics such as chi-square were used to compare the socio-demographic profiles between urban and rural consumers and t-test was used to compare urban and rural consumers' attitudes and beliefs regarding baobab fruits/pulp. We perform a preliminary exploratory factor analysis to check the internal reliability and dimensionality of the items measuring consumer attitudes and beliefs and the results are present later in Section 3. Second, we complemented the quantitative analysis with excerpts from the focus group participants as well as the industry interview.

3. Results

3.1. Quantitative results

3.1.1. Socio-demographic profile of baobab consumers in urban and rural markets

The comparison of socio-demographic profiles of urban and rural consumers of baobab are presented in Table 2. The results show that the proportion of males in the urban sample is less than that of the rural sample. However, there are more females in the urban sample than the rural sample. Urban and rural consumers have similar age groups, educational levels, and main occupations. However, more urban consumers earn higher incomes than rural consumers. In general, most consumers were reluctant to disclose the incomes.

3.1.2. Consumer behavior, attitudes, and beliefs toward baobab fruits/pulp

We find that most rural consumers purchased processed baobab fruits once a week while urban consumers bought them once every 10–14 days (Figure 1). Across the different consumers, small grocery stores were the preferred place of purchase for baobab fruits (Figure 2).

In Table 3, we show a cross tabulation between frequency of baobab purchase and demographic characteristics of the respondents. The results show that there is an association between frequency of purchase of baobab and education among urban consumers. However, with regard to rural consumers, age and education shows an association with frequency of baobab purchase (Table 3).

We performed a preliminary exploratory factor analysis to check the internal reliability and dimensionality of the items measuring consumer attitudes and beliefs. The internal reliability of the items was poor, as shown by low Cronbach alpha (under 0.60). The factor analysis did not reveal distinct patterns in the items, making it difficult to construct scores to represent consumer attitudes and beliefs. For this reason, we did not present the results for the factor analysis. This can be obtained upon request. This problem could be due to the quality of the questionnaire or the fact that baobab is a widely consumed food in the areas studied and equally popular among all consumer segments.

The general attitudes of consumers towards the consumption of processed baobab fruit products are presented in Table 4. In general, both urban and rural consumers express positive attitudes towards the consumption of baobab fruit pulp. For instance, they express positive outcomes such as feeling good, satisfied, pleasant, happy, well, and positive when consuming baobab fruit pulp (Table 4). However, rural consumers tend to have more positive attitudes towards baobab consumption.

The results of consumer beliefs about the attributes of baobab fruit pulp are shown in Table 5. We find that both urban and rural consumers express positive beliefs about attributes of baobab fruit pulp. They believe that baobab fruit pulp is cheap, available, ethical, nutritious, of good quality, good taste, sustainable, healthy, attractive, and special. However, they perceive baobab fruit pulp as less safe. We observe differences in perceptions of product attributes (especially price, safety, taste, quality, attractiveness) between urban and rural consumers, where rural consumers express stronger beliefs (Table 5).

In Table 6, we present the results on the extent to which social norms influence consumption of baobab fruit pulp. Urban and rural consumers perceive referents such as husband/wife, children, and family to be stimulating factors for the consumption of baobab fruit pulp. However, they are quite unsure as to whether friends and colleagues influence the consumption of baobab fruit pulp.

3.2. Qualitative results

3.2.1. Profile of focus group participants and baobab consumption

The group from El Obeid included participants between 25 and 68 years, whereas the group from Khartoum included seven participants aged between 18 and 61 years (Table 7). All participants recruited for the two focus group discussions were open-minded towards baobab fruit/pulp and they were knowledgeable about the baobab fruit/pulp as well. Participants' baobab fruit consumption patterns varied widely.

The baobab fruit/pulp is regularly purchased and consumed compared to other fruits, due to the health and nutrition value it provides. Further, focus group participants stated that baobab fruit/pulp is good medicine for disease such as malaria, diabetes, diarrhea, nephrotoxicity, and fever. All these diseases were mentioned by participants, who indicated that the baobab fruit/pulp is a treatment for the aforementioned diseases:

"I drink the baobab fruit/pulp juice when I become ill and am coughing; it's good for my body, and I recover, just when I drink a cup of it" (Man, age 48, married with four children, lives in El Obeid; FGD, 2018).

TABLE 2 Socio-demographic profile of Urban and Rural consumers of baobab.

Variable	Urban consumer (*N*=233)	Rural consumer (*N*=216)	Pearson chi-square statistics	*p*-value
Gender			12.38***	0.00
Female	50	34		
Male	50	66		
Age			3.35	0.501
18–24	9	14		
25–34	18	20		
35–44	28	26		
45–54	25	23		
55–above	19	16		
Education level			5.99	0.200
Primary school	45	42		
High school	22	31		
Tertiary	33	27		
Main occupation			2.38	0.30
Employee	16	12		
Worker	20	18		
Farmer	64	70		
Household income			38.23***	0.00
750–1,449 USD	20	32		
1,500–2,249 USD	16	14		
2,250–2,999 USD	16	9		
3,000–3,749 USD	12	6		
3,750–4,499 USD	7	3		
4,500 – above USD	7	0		
prefer not answer	22	35		

*** = 1% statistical significance. The values presented are percentages. Exchange rate in 2018. 1USD = 20 SDG. SDG refers to Sudanese pounds, the national currency of Sudan.

"I have had diabetes since three years ago. I did not go to a doctor from that time until now, and I used to drink baobab fruit/pulp juice when I would feel my diabetes was rising. When I drink it, I feel better "(Man, age 68, lives in El Obeid, FGD, 2018).

Generally, participants reported that they purchase the baobab fruit/pulp on many occasions, such as celebrations, weddings, and when they receive guests for special occasions:

"I buy the baobab fruit/pulp when I receive guests at home" (Woman, age 27, married with three children, lives in El Obeid, FGD, 2018).

"I drink the baobab fruit/pulp especially when I make delicious food. After I eat a meal, I drink it as another food ingredient" (Woman, age 47, married with two children, lives in El Obeid, FGD, 2018).

"I make baobab fruit/pulp juice for festivals, because it's local food and it's fresh, so most people need it" (Woman, age 32, married with five children, lives in Khartoum, FGD, 2018).

With respect to the season, respondents stated that consumption of the baobab fruit/pulp juice increases seasonally, especially during Ramadan (fasting time). A cup of the baobab fruit/pulp juice is perceived to be cool and refreshing:

"I drink baobab juice every day in the morning, before getting food or other drinks" (Woman, age 61, married, lives in Khartoum, FGD, 2018).

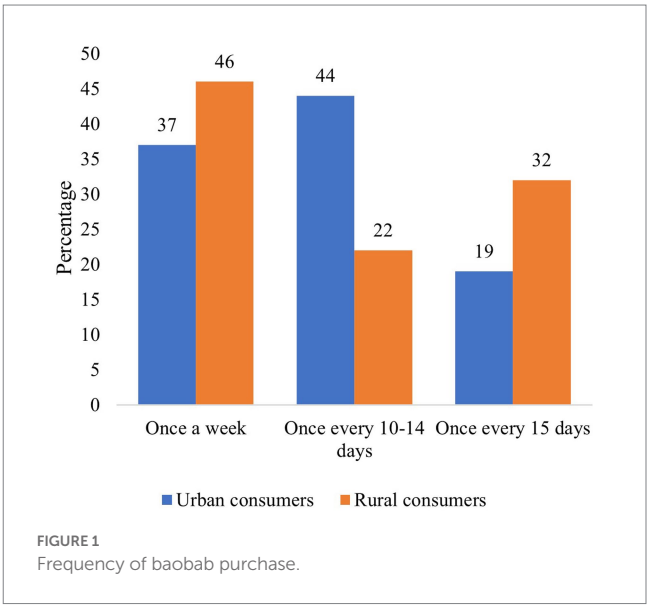

FIGURE 1
Frequency of baobab purchase.

"I prefer to drink baobab fruit/pulp juice especially in the month of Ramadan" (fasting time), (Woman, age 25, married with two children,

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TABLE 3 Cross tabulation between frequency of baobab purchase and demographic characteristics of consumers.

Variable	Urban consumers				Rural consumers			
	Frequency of purchase of baobab			Chi-square test	Frequency of purchase of baobab			Chi-square test
	Once every week	Once every 10–14 days	Once every 15 days	Value of *p*	Once every week	Once every 10–14 days	Once every 15 days	*p*-value
Gender				0.16				0.685
Male	19	58	39		46	34	63	
Female	25	44	48		23	14	36	
Age				0.978				0.058*
18–24	4	70	8		4	8	18	
25–34	7	19	15		16	8	20	
35–44	13	30	23		15	18	24	
45–54	9	25	25		24	7	19	
55 – above	11	18	16		10	7	18	
Education				0.371				0.070*
Primary school	21	7	16		33	12	45	
High school	44	29	29		22	17	29	
Tertiary	40	16	31		14	29	25	
Income				0.03**				0.885
750–1,449 USD	12	22	12		22	14	33	
1,500–2,249 USD	4	15	18		11	5	14	
2,250–2,999 USD	2	14	21		9	4	7	
3,000–3,749 USD	8	11	10		7	4	5	
3,750–4,499 USD	3	6	8		1	3	3	
4,500 – above USD	1	8	7		0	0	1	
Preferred not mention	14	26	11		22	18	36	

* and ** Denote 10 and 5% statistical significance level, respectively.

lives in El Obeid, FGD, 2018).

"In summer, when I go to a market and find the baobab fruit beverage, I buy and drink it because it lets me feel refreshed" (Woman, age 31, married with three children, lives in El Obeid, FGD, 2018).

"My father recommended I drink baobab fruit juice, so when I went to university, I found the shop for the baobab fruit beverage; I used to buy and drink it every day" (Student, age 18, lives in Khartoum, FGD, 2018).

Recurring themes reflected in conversations among the focus group participants are nutritional value, food safety, and pleasure-seeking. Furthermore, baobabs fruit/pulp has a special and festive character, which constitutes the main motives for purchase and consumption. One baobab participant confirms that quality is a strong issue in baobab powder, especially due to microbiological contamination.

"Baobab fruit/pulp juice is a special beverage to me, because it has a special taste and does not require a lot of preparation; it's easy to prepare it. Furthermore, Baobab fruit juice does not need more sugar" (Woman, age 37, married with four children, lives in Khartoum, FGD, 2018).

Other key motives for baobab fruit/pulp consumption are its perceived high nutritional value, unique taste, and health benefits:

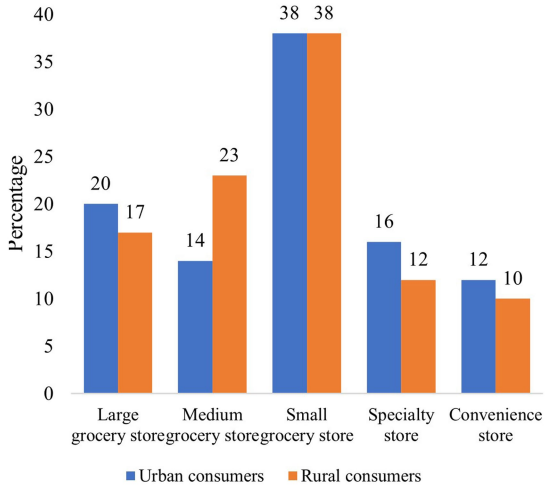

FIGURE 2
Place of purchase of baobab fruit products.

"Baobab fruit/pulp has a unique taste. The taste of baobab fruit/pulp juice is totally different from other fruit juices; it is an acidic taste"

TABLE 4 General attitudes towards baobab fruit products.

General attitude items	Urban consumer (*N*=233)	Rural consumer (*N*=216)	Mean difference	*t*-Test	*p*-value
I feel good/bad when I eat the baobab fruit pulp.	4.61 (1.02)	4.88 (0.56)	−0.27***	−3.33	0.00
I feel satisfied/unsatisfied when I drink the baobab fruit juice.	4.55 (1.14)	4.76 (0.84)	−0.21**	−2.20	0.03
I feel pleasant/unpleasant when I eat the baobab fruit pulp.	4.49 (1.15)	4.76 (0.82)	−0.27***	−2.80***	0.01
I feel happy/unhappy when I eat the baobab fruit pulp.	4.45 (1.18)	4.76 (0.86)	−0.31***	−3.13	0.00
I feel well/awful when I eat the baobab fruit pulp.	4.59 (1.03)	4.86 (0.66)	−0.26***	−3.21	0.00
I feel positive/negative when I eat baobab fruit pulp	4.67 (0.93)	4.76 (0.82)	−0.090	−1.09	0.28
Internal consistency (Cronbach alpha)	0.48	0.39			

The values in parentheses are standard deviations and those in front of the parentheses are mean scores. The items were measured on using a 5-point semantic differential scale. They include good/bad (1 = bad, 2 = slightly bad, 3 = neither good nor bad, 4 = slightly good, 5 = good), satisfied/unsatisfied (1 = unsatisfied, slightly unsatisfied, 3 = neither satisfied nor unsatisfied, 4 = slightly satisfied, 5 = satisfied), pleasant/unpleasant (1 = unpleasant, 2 = slightly unpleasant, 3 = neither pleasant nor unpleasant, 4 = slightly pleasant, 5 = pleasant), happy/unhappy (1 = unhappy, slightly unhappy, 3 = happy nor unhappy, 4 = slightly happy, 5 = happy), well/awful (1 = awful, 2 = slightly awful, 3 = neither well nor awful, 4 = slightly well, 5 = well), and positive/negative (1 = negative, 2 = slightly negative, 3 = neither positive nor negative, 4 = slightly positive, 5 = positive). *** and ** denote 1% and 5% statistical significance, respectively.

(Woman, age 57, single, lives in Khartoum, FGD, 2018).

"I consume the baobab fruit/pulp juice because I believe that it has some characteristics and properties and contains different vitamins" (Man, age 58, married with six children, lives in El Obeid, FGD, 2018).

"The color of baobab fruit/pulp is one of best characteristics that attracted me. If I am at a market and I see baobab fruit/pulp, I buy it directly, without hesitation, as it looks so nice and tasty" (Woman, age 41, with four children, lives in Khartoum, FGD, 2018).

"When I become pregnant, I used to drink and soak up baobab fruit/pulp and juice" (Woman, age 46, with five children, lives in Khartoum, FGD, 2018).

On the other hand, the low income of consumers and the perception of the baobab fruit/pulp as expensive constitute barriers to purchase and consumption:

"I prefer baobab fruit/pulp juice, but sometimes I do not have enough money to buy it or my circumstances do not allow me to purchase it regularly" (Man, age 50, married with two wives and seven children, lives in El Obeid, FGD, 2018).

In particular, its price is a limiting factor to more regular and frequent purchase routines:

"I used to buy baobab fruit/pulp early, before the season of harvesting finished, because in that time the price of baobab is lower. Otherwise, I ultimately find it too expensive" (Woman, age 42, married with five children, lives El Obeid, FGD, 2018).

3.3. Analysis of the development potential of baobab fruit/pulp markets

The results of the SWOT analysis are presented in this section and summarized in Figure 3. We treated strengths and weaknesses as all factors that are under control of the value chain actors including consumers while opportunities and threats are regarded as external factors outside the control of the actors.

3.3.1. Strengths

The stakeholder interviews reveal that baobab fruits/pulps are associated with many nutritional benefits such as being rich in dietary soluble and insoluble fibers, calcium, iron, potassium, and magnesium. Baobab fruits/pulps also have a unique taste (Figure 3).

3.3.2. Weaknesses

However, the interviewees mentioned that the baobab fruit/pulp value chain has many weaknesses, namely no standard formulation, a lack of proper packaging and storage materials, loss of vitamin C in the processing of baobab pulp, poor distribution, and insufficient supply of baobab fruits (Figure 3).

3.3.3. Opportunities

As indicated by the interviewees, many opportunities exist in the baobab fruit/pulp value chain in Sudan. These include high demand for the product, export opportunities, available technology to improve product quality, and the extraction of ingredient for commercial purpose (Figure 3).

3.3.4. Threats

Inadequate quality control and measures, a lack of marketing and regulations, and high barriers to exports are some of the threats to the development of the baobab fruit/pulp value chain (Figure 3).

4. Discussion

The findings reveal that consumption of processed baobab fruit products is common among consumers in urban and rural markets in Sudan. This result is consistent with evidence from Adam (2017) of a high demand for baobab fruits and secondary products in El Obeid and Khartoum markets in Sudan. Demographic characteristics such as age, education and income tend to influence

TABLE 5 Consumer beliefs regarding attributes of baobab products.

Belief items	Urban consumers (*N*=233)	Rural consumers (*N*=216)	Mean difference	*t*-Test	*p*-value
I consider the baobab fruit's pulp cheap/expensive	4.70 (0.94)	4.94 (0.27)	−0.24***	−3.63	0.00
I believe that baobab fruit pulp is available/not available.	4.95 (0.21)	4.97 (0.18)	−0.02	−0.78	0.43
I think that the baobab fruit pulp is ethical/not ethical.	4.96 (0.30)	4.96 (0.35)	0.00	0.00	0.92
I consider the baobab fruits pulp safe/not safe	1.54 (0.84)	2.35 (1.46)	−0.81***	−7.28	0.00
I believe that baobab fruit pulp is nutritious/not nutritious.	4.89 (0.45)	4.81 (0.67)	0.08	1.55	0.12
I believe that baobab fruit pulp and juice has good taste/bad taste	4.71 (0.66)	4.85 (0.43)	−0.14***	−2.65	0.01
I believe that baobab fruit pulp has good quality/bad quality.	4.94 (0.33)	5.00 (0.07)	−0.06**	−2.43	0.02
I believe that baobab fruit pulp is sustainable/not sustainable.	4.97 (0.21)	4.96 (0.30)	0.01	0.11	0.92
I believe that baobab fruit pulp is healthy/not healthy.	4.97 (0.18)	4.97 (0.24)	0.00	0.00	0.92
I believe that baobab fruit pulp is attractive/not attractive	4.92 (0.36)	4.98 (0.15)	−0.06**	−2.23	0.03
I believe that baobab fruit pulp is special/not special.	4.94 (0.40)	4.97 (0.24)	−0.03	−0.88	0.38
Internal consistency (Cronbach alpha)	0.25	0.07			

The values in parentheses are standard deviations and those in front of the parentheses are mean scores. The items were measured on using a 5-point semantic differential scale. Expensive/cheap (1 = expensive, 2 = slightly expensive, 3 = neither expensive nor cheap, 4 = slightly cheap, 5 = cheap), unavailable/available (1 = unavailable, 2 = slightly unavailable, 3 = neither available nor unavailable, 4 = slightly available, 5 = available), unsafe/safe (1 = unsafe, 2 = slightly unsafe, 3 = neither safe nor unsafe, 4 = slightly safe, 5 = safe), not nutritious/nutritious (1 = not nutritious, 2 = slightly not nutritious, 3 = neither not nutritious nor nutritious, 4 = slightly nutritious, 5 = nutritious), bad/good taste (1 = bad taste, 2 = slightly bad taste, 3 = neither bad nor good taste, 4 = slightly good taste, 5 = good taste), bad/good quality (1 = bad quality, 2 = slightly bad quality, 3 = neither bad nor good quality, 4 = slightly good quality, 5 = good quality), unsustainable/sustainable (1 = unsustainable, 2 = slightly unsustainable, 3 = neither unsustainable nor sustainable, 4 = slightly sustainable, 5 = sustainable), unhealthy/healthy (1 = unhealthy, 2 = slightly unhealthy, 3 = neither unhealthy nor healthy, 4 = slightly healthy, 5 = healthy), unattractive/attractive (1 = unattractive, 2 = slightly unattractive, 3 = neither unattractive nor attractive, 4 = slightly attractive, 5 = attractive), and not specially/specially (1 = not speci1ally, 2 = slightly not specially, 3 = neither not specially nor specially, 4 = slightly specially, 5 = specially). *** and ** denote 1% and 5% statistical significance, respectively.

the consumption of baobab. For instance, we find that most urban consumers in the lower income categories are more likely to purchase baobab frequently compared those in the higher income groups. However, evidence from Kiprotich et al. (2019) showed no relationship between consumer income and intensity of utilization of baobab products in Kenya. We also observe an association between frequency of baobab purchase and education among rural consumers, with less educated consumers tending to purchase baobab frequently compared to educated ones. This is consistent with existing literature showing that some educated Africans have a lower preference to consume traditional and indigenous African foods (Fungo et al., 2016; Kiprotich et al., 2019). In addition, we find an association between frequency of baobab purchase and age of rural consumers. The result shows that as consumers in older age categories tend to purchase baobab more frequent. The reason could be that older generations are more aware of the health benefits of baobab and therefore more inclined to buy it frequently. The most popular place of purchase for the population is small grocery stores because of the low price. The results also point out the integration of baobab fruit products into formal outlets such as large and medium-sized grocery stores. These results emphasize the potential for commercialization and upgrading of baobab value chains in Sudan.

Results from the qualitative and quantitative studies indicate that consumers, especially rural consumers, have positive attitudes towards the consumption of baobab fruits pulp. They perceive that the consumption of baobab fruit pulp is associated with positive outcomes such as feeling good, satisfied, pleasant, happy, well, and positive. This result is consistent with the findings of Kiprotich et al. (2019) on baobab fruit and the consumption of urban and rural consumers in Kenya, who also reported that consumers mostly have positive attitudes toward baobab fruits and pulp consumption. The findings are also consistent with those of Sabbe et al. (2008), who showed positive perceptions towards tropical fruits among Belgian consumers. This evidence may indicate the functional properties of baobab and its ability to positively shape people's moods.

Consumers also hold strong, positive beliefs about the attributes of baobab fruit pulp. The attributes are related to health (nutritious, healthy), sensory appeal (taste, attractiveness), safety and quality, and ethical concerns (sustainable, ethical). Nutritional and health benefits are the main motivating factors for consumption of baobab, which also supports the finding of Adam (2017) that nutritional value

TABLE 6 The extent social norms influence consumption of baobab fruit pulp.

Referents	Urban consumers (*N*=233)	Rural consumers (*N*=216)	Mean difference	*t*-Test	*p*-value
Husband/wife	4.94 (0.40)	4.94 (0.41)	0	0.00	0.99
Children	4.85 (0.61)	4.94 (0.38)	−0.09*	−1.85	0.06
Family	4.91 (0.35)	4.90 (0.39)	0.01	0.08	0.94
Friends	3.66 (1.82)	2.87 (1.96)	0.79***	4.40	0.00
Colleagues	3.43 (1.83)	2.54 (1.83)	0.89***	5.16	0.00

A 5-point differential semantic scale (inhibiting/stimulating factor: 1 = inhibiting factor, 2 = slightly inhibiting factor, 3 = neither inhibiting nor stimulating factor, 4 = slightly stimulating factor, 5 = stimulating factor) was used to measure the extent to which the referents inhibit or stimulate the consumption of baobab fruit pulp. * Denotes 10% statistical significance and *** denotes 1% statistical significance.

TABLE 7 Characteristics of focus groups participants.

Participant	Gender	Age	Frequency of consumption
Focus group 1 (*N*=9)			
1	Male	48	One time a week
2	Male	58	1–3 time a week
3	Male	31	Ramadan
4	Male	68	One time a day
5	Female	42	Multiple time week
6	Female	27	Two time a month
7	Male	50	2–3 time a day
8	Female	25	One time a month
9	Female	47	Multiple time a day
Focus group 2 (*N*=7)			
1	Female	41	Three time a month
2	Male	46	One time a week
3	Female	32	Two time a day
4	Female	37	1–2 time a week
5	Male	57	Multiple time a week
6	Female	61	More than three time a week
7	Male	18	Multiple time a year

(vitamins) is a stimulating factor for the high demand of baobab in Sudan. Sudanese consumers are concerned about healthy eating and food-related diseases, which is reflected in a growing interest in nutrient-rich and health-benefiting fruits. In addition, consumers look for natural fruits with health benefits. The baobab fruit/pulp industry needs to focus on innovation and to constantly search for natural food products with a healthy image. As reported in the qualitative study, baobab fruit pulp is used to treat health-related diseases. This is confirmed by previous studies that indicated that baobab is used for medicinal purpose in Ethiopia (Abere et al., 2022), Burkina Faso (Schumann et al., 2012), Malawi (Sanchez, 2011), Sudan and Kenya (Gebauer et al., 2016). Consumers also find baobab fruit pulp to be associated with good sensory appeal; that is, it has a good taste and is very attractive. This sensory appeal could motivate people to consume baobab locally. However, consumers express great concerns regarding the safety of baobab fruit pulp. This may be related to poor handling practices in the processing of baobab pulp. Baobab fruit pulp can become moldy, especially when collected during rainy season, and it can be contaminated by mycotoxins (Meinhold and Darr, 2022). In addition, consumers also believe that baobab fruit pulp is ethical and sustainable as its harvesting and processing are associated with minimum environmental impacts.

The SWOT analysis reveals internal strengths and opportunities, as well as weaknesses and threats to the development of baobab markets. In terms of strengths, the baobab fruit/pulp is well known as a domestic, natural product that is rich in dietary soluble and insoluble fibers, and which has been consumed by the local people for centuries. Recently, however, baobab fruit and pulp have attracted the interest of consumers at local level due to their high nutritional content and functional properties, especially vitamin C, natural sugar, and pectin (Yazzie et al., 1994; Gadour et al., 2017; Lisao et al., 2017; Muthai et al., 2017; Aragaw et al., 2021). The acidic taste is attributed to the presence of organic acids such as citric acid, tartaric acid, malice acid, and succinic acid. Baobab fruits have the potential to be stored for a long time; this distinguishes them from other garden fruits. The fruits can be stored before the fruit capsule is crushed: this is a unique feature of baobab fruits.

However, there are some weaknesses associated with baobab, which include no standard formulation, poor packaging and storage, poor distribution and lack of knowledge and technical skills to improve quality of product. In marketing of baobab, there are no standard measuring scale, which makes it difficult to estimate the actual quantities of baobab sold. Collectors also have very basic knowledge with respect to harvesting tools, packaging, and storage activity. Furthermore, the fruits are broken and opened by chimpanzees and baboons and can crack open if they fall on a stony surface. The quality of the products suffers as a result of the fruits being exposed to dust and sand during harvesting. Fruits are sometimes harvested unripe due to intense competition among collectors, resulting in a scarcity of quality, especially tasty fruits. There are also some issues with storage techniques, as insects attack the products, lowering their quality and, as a result, affecting their taste or appearance. There is a lack of processing industries, advanced knowledge, and technical skills to improve the processing technologies and to guarantee constant good quality of the final product. Baobab fruit/pulp is generally obtained by using traditional processing systems, crushing the capsule of fruit. Inadequate supply and inconsistent baobab fruit/pulp quality may hamper its use in the development of innovative fruit/pulp.

Many opportunities exist in baobab value chains, including high demand for the product, export opportunities, available technology to improve product quality, and the extraction of ingredients for commercial purposes. The local markets for baobab fruit/pulp and their juice have existed for centuries. Baobab business experts confirmed this finding, as they are seeking to meet the increasing

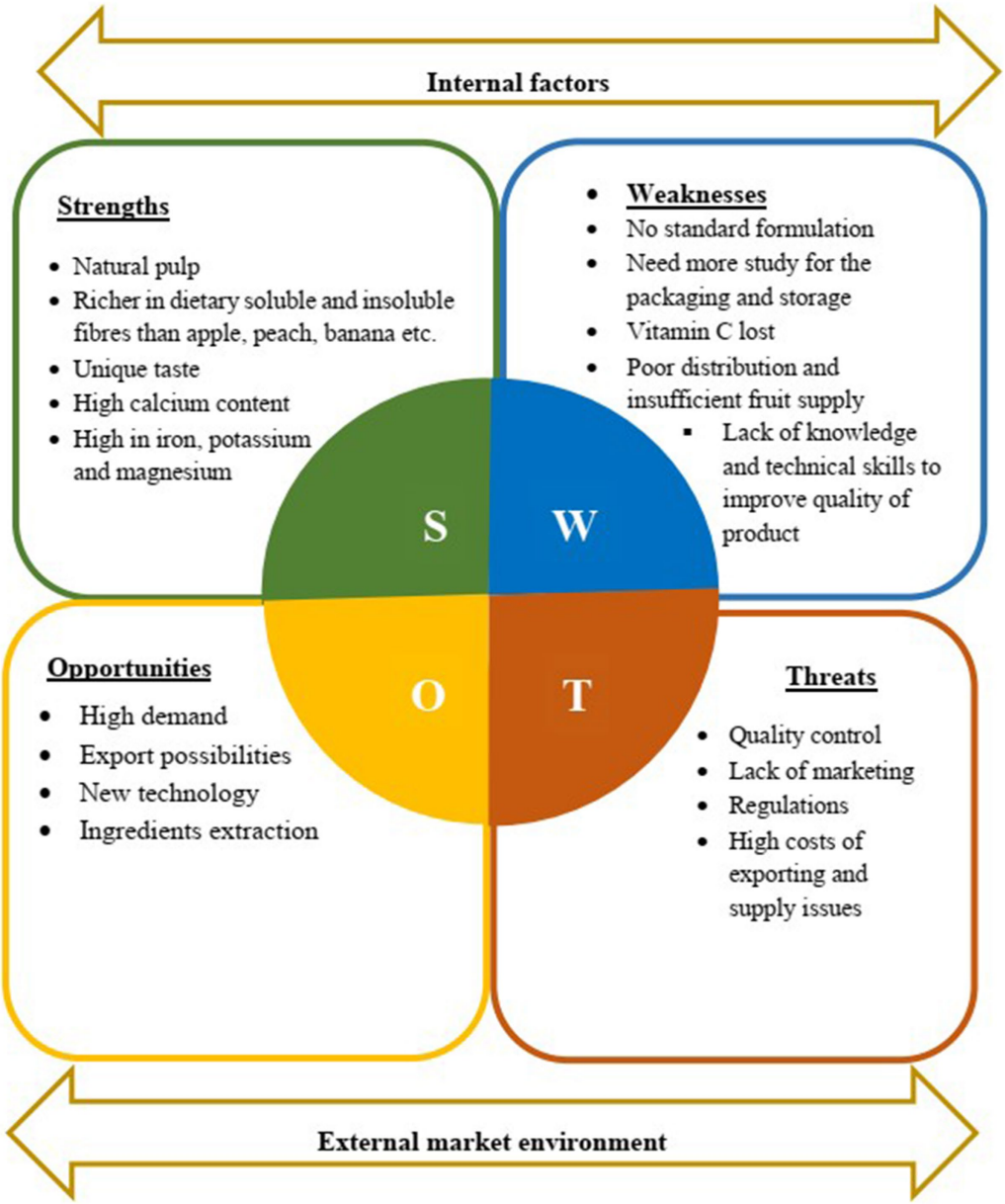

FIGURE 3
SWOT analysis of the baobab markets in Sudan.

demand through innovations, e.g., through adding new flavor. In addition, they mentioned that local consumers continue showing their preferences for the baobab fruit and pulp consumption as a traditional local food. The baobab fruit and pulp market can be expected to continue growing with opportunities for product differentiation. Significant opportunity lies in the growing demand for fruits due to outstanding nutritional characteristics, which provide health-related benefits. Further innovation may take advantage of the already existing local processing industries and hence practical knowledge about processing technologies and uses of baobab fruit/pulp. Experiences from national processing industries and well-developed domestic markets may eventually lead to international market environments. For example, profits realized on national markets may act as a buffer for the risks associated with the exploration of international markets with strict regulatory environments and end users that demand high quality. Advanced skills and knowledge about baobab fruit/pulp production, transportation, and processing issues are barely available to producers. In addition, the inconsistent quality of baobab fruit/pulp is a very relevant weakness when considered alongside the strict market access requirements regarding food quality and safety.

However, there are some threats which may hinder the exploration of the identified opportunities. Interviewees reported that there are many constraints associated with the *A. digitata* fruit/pulp industry. The main threat mentioned by business stakeholders of the baobab fruits/pulp juice industry was the costs of raw materials, due to the high price of the fruit. Due to higher demand for baobab fruits and pulp, and the low availability of the baobab fruit/pulp during the period of Ramadan (fasting time), companies still faced difficulties in consistent supply of baobab fruits and pulp. Further constraints mentioned by interviewees were high transportation costs and market access requirements due to taxation.

Stakeholders perceived compliance with good manufacturing practice from the International Organization for Standardization and the International Labour Organization as further threats to the growth of the business but agreed that those requirements should be met by suppliers in order to meet the increasing demands of consumers with respect to health, sustainability, quality, and safety issues. Another important constraint pointed out by interviewees was the seasonality in demand for baobab fruit and pulp products, with a sharp decline in demand after Ramadan. The existence of traditional traders of baobab fruit pulp and juice in marketplaces are perceived as strong competition for processing companies, since baobab fruit pulp and juice consumers prefer the fresh juice of baobab fruit/pulp over ready-to-drink processed baobab fruit juice.

5. Conclusion and recommendations

The present study was conducted in two market locations (urban and rural) in Sudan with distinct socioeconomics characteristics. The study combines results from a convenience sample of 449 consumers, as well as focus group discussions and an interview with a food industry expert. Results consistently show positive attitudes and beliefs regarding baobab consumption and its social integration and acceptance. In conclusion, further market development for baobab products seems promising in Sudan. For further development of local markets, marketing strategies need to be developed that highlight the nutritional and functional properties of baobab fruit and its ability to combat diseases. The marketing strategies could target lower income group, less educated people and older people while high income class, educated and young people need to be sensitized to the health and nutritional benefits of baobab. In addition, processors need to improve the quality and safety of the products to attractive more people to consume the products. Policymakers also need to develop a regulatory framework that supports the baobab value chain in Sudan.

This study's limitations are as follows. First, the study was mainly exploratory and did not analyze how consumer attitudes, beliefs, and social norms influence their behavior towards the consumption of baobab fruit pulp. We could not perform this analysis due to low internal reliability of the items measuring attitudes and beliefs. For this reason, we suggest further testing of the questionnaire in future research, which should also incorporate additional cities and marketplaces in Sudan and increase the sample size to strengthen the robustness of the results. Our study incorporated only a few focus group discussions and stakeholder interviews, which cannot represent the views and experiences of all stakeholders in the sector. Therefore, we recommend that future research should build on our study by increasing the number of focus group discussions and stakeholder interviews. Notwithstanding the seasonality of the product, and the fluctuations in supply and demand over different months in different years, the study's data refer to the study year only. In order to compensate for seasonality, we recommend conducting market analysis in different months and different years. The study's findings, especially the SWOT analysis, could be applicable to other African countries where baobab is present. However, further studies from other regions in Africa could facilitate the comparison and generalization of findings. Such studies would also contribute to analyzing how differences in culture and regions correlate with consumer attitudes and behavior towards baobab consumption.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

HS: conceptualization, methodology, investigation, data curation, data analysis, validation, and writing of original draft. DM and YA: planning, and supervision of the study, funding and revision of manuscript. ED: revision of manuscript and data analysis. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2023.1118714/full#supplementary-material

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EDITED BY
Joanita Kataike,
Mountains of the Moon University, Uganda

REVIEWED BY
Anna Maria H. Häring,
Eberswalde University for Sustainable Development, Germany
James Hale,
Colorado State University, United States

*CORRESPONDENCE
Pascal Grohmann
✉ pascal.grohmann@hu-berlin.de

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Governance and trust in sustainability-based agri-food value chains. A comparative analysis of five cases in Germany

Pascal Grohmann[1]*, Victoria Dietze[1], Christine Krämer[2,3] and Peter H. Feindt[1]

[1]Agricultural and Food Policy Group, Thaer-Institute of Agricultural and Horticultural Sciences, Humboldt-Universität zu Berlin, Berlin, Germany, [2]Institute of Rural Studies, Thünen Institute, Federal Research Institute for Rural Areas, Forestry and Fisheries, Braunschweig, Germany, [3]Projektbüro mareg markt + region, Ippesheim, Germany

Value chains that generate an increased willingness to pay among consumers by offering enhanced levels of sustainability are widely discussed as an important strategy for creating new business opportunities and fostering food system transformation. Previous research has highlighted the importance of governance arrangements to secure the trust necessary for the establishment of sustainability-based value chains. However, how different coordination designs by private and public actors along the value chain affect trust formation is not well understood. To address this question, this paper combines the concepts of hybrid governance and multidimensional trust to guide a comparative analysis of five sustainability-based agri-food value chains in Germany as exemplary case studies. The findings show that different types of governance activities are necessary to build the capacity to address four different sources of trust: dispositional, affinitive, rational and procedural trust. Building trust capacities facilitates coordination of activities along the value chain and reliable delivery of sustainability-related value propositions. In all five cases, governance arrangements and building of trust capacities were geared towards increasing willingness to pay. Sustainability-based agri-food value chains have therefore limited potential to internalize the agri-food sector's substantial negative externalities.

KEYWORDS

credence goods, information assymetries, hybrid governance, trust, coordination, external effects, food systems, transformation

1. Introduction

Value chains built on special sustainability merits such as high levels of biodiversity protection, animal welfare, water protection or good labor conditions are currently discussed as an important strategy to transform agricultural and food systems towards more sustainability while maintaining or even increasing farm income (Ruben et al., 2021). Increasing both sustainability and farm income at the same time, however, will in most cases require a higher willingness by consumers to pay for the products (Nuppenau, 2019), which is typically generated by value propositions that pair claims to product quality and sustainability benefits. To deliver on such complex value propositions, coordination is required along the entire value chain (Carbone, 2017).

Encompassing a broad range of activities needed to transfer a good or service from production to consumption (Porter, 1985), value chains constitute "complex systems comprising networks of interdependent actors that cooperate and create value" (de Vries et al., 2022). Forming and maintaining value chains entails various challenges, which depend, *inter alia*, on product types, market conditions, stakeholder structure and environmental factors (Peterson, 2009). Sustainability-based agri-food value chains must not only solve problems in production modes, management practices, technological innovations, and consumer behavior (Pérez-Mesa et al., 2019) and acquire capacities in leadership, innovation, entrepreneurship, knowledge and learning (Peterson, 2009; Braun et al., 2022); similarly important is overcoming information asymmetries which arise from the sustainability claims at the core of the value proposition. The sustainability attributes refer to process characteristics which cannot be verified by customers through sensory experience of the product at the point of sale; this is a general characteristic of credence goods (Gachukia, 2015). The ensuing information asymmetry enables fraud and can lead to a collapse of markets or prevent their development in the first place (Akerlof, 1970). It generates a problem of trust which occurs along the entire value chain. Governance arrangements are needed to assure buyers at each stage of the value chain that the sustainability claims can be trusted (Anania and Nisticò, 2004).

Consequently, the interplay of governance and trust in agri-food value chains has been identified as a major challenge for research and practice (Pilbeam et al., 2012; Ingram et al., 2018; van Bers et al., 2019; Fielke et al., 2020; Assis et al., 2022; de Vries et al., 2022). Value chain governance typically comprises various modes of steering, for example, hierarchical or market coordination (Pilbeam et al., 2012; Ingram et al., 2018; Kataike and Gellynck, 2018). The governance of agri-food value chains is closely linked to food regulation and often involves a "hybrid" interplay of actors from the public, private and civil society sectors (Marsden et al., 2009; Verbruggen and Havinga, 2018). From the perspective of the value chain actors, the main purpose of value chain governance is coordination of activities to create business opportunities, while public and civil society actors are typically more interested in food safety and health, consumer protection and sustainability. Trust in product safety and the reliability of sustainability claims links both sets of interests. Suitable governance arrangements are a precondition to create and preserve trust.

This paper addresses the question how governance arrangements generate and maintain trust in sustainability-based agri-food value chains. For this purpose, we combine a hybrid governance perspective with a multidimensional concept of trust (Stern and Coleman, 2015; de Vries et al., 2019). We aim to understand how governance arrangements in agri-food value chains address different sources of trust and which capacities the value chain actors deploy for this end. We develop a conceptual framework on the relationship between value chain governance, trust formation and value chain capacities and conduct a comparative analysis of five agri-food value chains in Germany. We thereby aim to contribute conceptually and empirically to current discussions on hybrid governance (Verbruggen and Havinga, 2018) and the role of trust in value chains built on special sustainability claims (de Vries et al., 2022), with a view to understanding the role of such value chains in the sustainability transition of the agri-food sector (Marsden, 2013; Brunori et al., 2016; Ruben et al., 2021).

The remainder of this paper proceeds as follows. Section 2 sets out the conceptual framework to analyze the links between agri-food value chain governance and trust formation in agri-food systems. Section 3 describes the methodological approach of the comparative case analysis. Section 4 presents the findings from five agri-food value chains in Germany, in particular the impact of governance arrangements on trust formation, and on the required trust capacities. Section 5 contextualizes the results with current discussions on (hybrid) governance of the transformation in agri-food systems.

2. Conceptual framework

2.1. External effects in agri-food value chains

Agri-food value chains have been conceptualized in different ways (Donovan et al., 2015): first, based on Porter (1985), as the various *activities* to produce, process, trade and consume an agricultural product (Theuvsen and Spiller, 2007); second, as a set of *actors* connected through interactions (Riisgaard and Ponte, 2011); third, as *networks* of actors (da Silva and de Souza Filho, 2007). These conceptualizations are complementary since the activities are carried out by actors who are connected in networks (Donovan et al., 2015). Consequently, de Vries et al. (2022) define agri-food value chains as

> "complex systems comprising a network of interdependent actors that cooperate to capture and create value by responding to consumer demand through a wide range of practices […] including production, harvesting, bulking, processing, trading, packaging, and retailing of food." (de Vries et al., 2022, p. 176)

Agri-food value chains are embedded in natural and institutional environments, that is, the broader agri-food system (Hospes and Brons, 2016), where they might create external effects, describing costs or benefits which are not reflected in the price of the products (Ericksen, 2008). These can be either positive, such as provision of food security, ecosystem services or regional development (Ingram et al., 2018), or negative, for example, through resource depletion or pollution. The market failure induced by these external effects is the main rationale underlying calls for a transformation of the governance of agri-food value chains (Ingram, 2011) and food systems more broadly (Ruben et al., 2021).

Many external effects of agri-food value chains originate from the fact that agricultural systems provide not only private but also public goods (Meuwissen et al., 2019). While there are markets for the former, the latter, for example attractive and diverse landscapes, have long been taken for granted as by-products of farming (Ebert, 1998). Many agricultural activities, however, have detrimental effects on the condition of public goods such as climate, biodiversity, water quality and landscape amenity. Public policies have attempted to reduce negative externalities through regulation and financial remuneration of less damaging practices (Nuppenau, 2019), for example through the integration of environmental objectives and instruments in the Common Agricultural Policy (CAP) of the European Union (Feindt, 2010; Grohmann and Feindt, 2023). In parallel, markets have developed where some consumers are willing to pay higher prices for products with higher positive externalities and/or lower negative

externalities, organic products being a prime example. Many of the sustainability claims in these value chains directly address the provision of public goods or reduced negative externalities. Increasing interest and willingness to pay for goods produced with increased sustainability benefits has been observed if the benefits are credibly communicated (Hemmerling et al., 2015).

However, the sustainability claims made by producers, processors and sellers can usually not be verified at the point of sale. The "sustainable" products are credence goods, which means that individual consumers cannot check the attributes which are decisive for the purchasing decision and the higher willingness to pay without incurring prohibitively high costs (Anania and Nisticò, 2004). The ensuing information asymmetry between the value chain actors (Shen et al., 2019; Vosooghidizaji et al., 2020) inhibits the development of markets for such goods (Akerlof, 1970) unless suitable governance mechanisms create trust in the reliability of claims (Gachukia, 2015).

2.2. Coordination activities in agri-food value chain governance

Governance in agri-food chains entails the multiple steering mechanisms that coordinate the activities among the value chain actors (based on: Havinga et al., 2015; Ingram et al., 2018). Coordination is normally enabled through rules that codify expectations and obligations. While simple value chains with low levels of risk involved and patterns of frequent interaction might work based on informal rules, coordination in more complex value chains usually requires formal rules. Generally, coordination activities in agri-food value chains must fulfill five essential functions (Abbot and Snidal, 2009; Havinga, 2015; see Table 1): *Rule-making* involves agenda setting, defining goals, as well as negotiating and formulating concrete rules. If the political, social or economic environment changes, the objectives and rules may need revision or reformulation. The second and third coordination activity are *adoption* and *implementation* of the rules. This typically involves a formal process that obliges suppliers and customers to comply with the rules, and instigating the measures necessary for compliance. *Monitoring* the rules generally requires the periodic conduct of tests, inspections, and audits, the certification of products, and the ongoing documentation of the measures or product characteristics specified by the rules in order to be able to track misconduct. *Enforcement* of the rules includes various forms of internal sanctions, such as warnings, contractual penalties or withdrawal of certification, but also legal sanctions that must be enforced in court. The sanctions must be defined in the rule system to be behaviorally effective and generate legitimacy.

TABLE 1 Functions and coordination activities in agri-food chains.

Function	Coordination activity
Rule making	Agenda setting Determining the objectives Negotiating and drafting concrete rules
Adoption	Adopting the rules Imposing the rules on value chain actors
Implementation	Implementing the rules and measures
Monitoring	Testing, inspecting, auditing Certifying Documenting Tracing non-compliance
Enforcement	Internal sanctioning Legal sanctioning

Own representation based on Havinga (2015, p. 32).

The increasing complexity and internationalization of contemporary food value chains is mirrored by a proliferation of governance activities that complement national public regulations, such as private and international standards and regulatory systems, a process that has been described as "hybridization of food governance" (Verbruggen and Havinga, 2018). Hybrid governance arrangements imply an interplay of private and public actors within each of the coordination activities and between two or more activities (Verbruggen and Havinga, 2015). An example of the former is the joint development of standards by government institutions and farmers' associations; an example of the latter would be the delegation of monitoring of government standards to private institutes. Importantly, while the five functions of coordination activities logically build upon each other, in practice the activities are often overlapping or cyclical.

2.3. Trust in sustainability-based agri-food value chains

The five functions and coordination activities in hybrid food governance create conditions that enable collaboration by reducing the risk of investing in activities that create benefits only if the expected behaviors of others are fulfilled – for example, if the wholesaler pays the expected higher price for sustainably produced crops. All five functions are therefore directly relevant for the creation and maintenance of trust along the value chain. While trust has been studied by many disciplines, the basic conceptualization is "not so different at all" (Rousseau et al., 1998). The notion of trust mostly refers to a willingness to accept vulnerability regarding the outcomes of an interaction, based on positive expectations about the intentions or behavior of others (Mayer et al., 1995; Bauer, 2021). From a systems theoretical perspective, trust reduces complexity in social interactions, as does distrust, but with different outcomes (Luhmann, 1988).

The *functions* of trust in agri-food value chains have been widely discussed. Trust is seen as a prerequisite for interactions and commercial success (Troy et al., 2016), an enabler of collaboration (Mankad et al., 2017; Dania et al., 2018) that also helps to reduce transaction costs (Bair, 2008; Martino, 2011), and a facilitator of the sustainability performance in agri-food value chains (Chen et al., 2017). However, few connections have been made to the literature on the *formation* of trust. Mayer et al. (1995) focus on personal characteristics, including the ability, benevolence and integrity of an actor. De Vries et al. (2019) distinguish between trust based on personal relationships ("trusting the people") and trust based on perceptions of the institutional frameworks as reliable ("trusting the system"). Stern and Coleman (2015) differentiate even four possible sources of trust (see Table 2): (1) Dispositional trust describes the propensity of individuals to trust institutions, organizations, office holders, or other people. (2) Affinitive trust is based on shared experiences, values, identities or networks. (3) Rational trust is built on a calculation of expected benefits and risks based on the information available at the time and on fulfilled or disappointed

TABLE 2 Types and sources of trust.

Type	Sources
Dispositional trust	Institutions and organisations Positions People
Affinitive trust	Shared experiences Shared values and identities Shared networks
Rational trust	Information on expected benefits and costs Fulfilled expectations in the past
Procedural trust	Procedural legitimacy Transparency Fairness

Own representation based on Stern and Coleman (2015, p. 122).

expectations in the past. (4) Procedural trust refers to the perceived legitimacy, transparency and fairness of procedures and processes that allow reliable predictions to be made about the behavior of others.

Research on trust in agri-food value chains has focused on consumers' trust (Macready et al., 2020), particularly in single actors along the food chain, for example, farmers (Moore, 2006), manufacturers (James, 2006) or retailers (Rampl et al., 2012). Previous studies on the relationship between trust and governance in agri-food value chains have concentrated particularly on the potential of market, hierarchical or hybrid governance to reduce transaction costs (Martino, 2011), whereas limited attention was given to the differentiation of individual governance activities (for a recent exception, see: Weber and Wiek, 2021) or to different types of trust.

3. Materials and methods

To address the research question of how governance arrangements generate and maintain trust in sustainability-based agri-food value chains, we have conducted a comparative analysis of five cases in Germany, based on a qualitative analysis of documents and in-depth expert interviews. Such a research design is well established in studies of trust in agri-food value chains (de Vries et al., 2022). Comparative analyses allow for a systematic comparison of specific phenomena (Chen et al., 2021; Michel et al., 2022), while considering their concrete contexts in order to contribute to a better understanding of the phenomena under investigation (Yin, 2017). They permit to generate new insights for the further development of conceptual considerations on the basis of empirical findings (Flyvbjerg, 2006).

3.1. Case selection

The selection of the five cases of sustainability-based agri-food chains followed a systematic approach. As a first step, we conducted a desk research and compiled a database of 50 projects, brands, initiatives and companies in Germany that claim to commercialize agricultural products with special sustainable characteristics (see Supplementary material A). Only agri-food chains in Germany were included to ensure similar market conditions as well as economic and institutional frameworks across cases. Economically, Germany provides relatively favorable conditions due to relatively high demand and willingness to pay for sustainably produced food. The institutional framework is shaped by the EU's CAP, which provides income support for farms that is made conditional to compliance with basic environmental, health and animal welfare requirements as well as financial remuneration of more sustainable farming practices, for example, support of organic farming or agri-environmental and climate measures. Despite the inclusion of many sustainability-related goals and instruments in the CAP, negative externalities of agriculture in the EU have not been effectively internalized (Pe'er et al., 2019). This persisting market failure allows products from unsustainable production systems to dominate the market and thereby provides the space and rationale for sustainability-based agri-food chains.

Five characteristics were recorded for each of the 50 agri-food chains included in the database: product type, sales channel, sustainability claim, number of different groups of value chain actors (for example producers, processors, retail) and coordinator. The recorded examples showed very different combinations of characteristics. We selected five cases following the principle of contrast (sampling of extreme cases) which means the aim was to achieve the greatest possible dissimilarity with regard to the characteristics (Silverman, 2017, p. 268) and to include different forms of sustainability-based value chains. One of the authors pre-selected 10 possible cases from the 50 recorded examples, with value chains representing a broad range of different product types, sustainability benefits (according to self-representation of the initiatives) and governance arrangements (sales channels, number of different value chain actor groups and coordinators). The pre-selected cases were discussed by the entire project team and five cases were selected which present the strongest possible contrast along the characteristics. The result of the case selection is summarized in Table 3 which shows the five cases and their characteristics.

3.2. Description of the cases

The first case, *Wasserschutzbrot* ("water protection bread"), is a project of the district government of Lower Franconia (South Germany) that started in 2014 as part of the overall strategy on groundwater protection by the Bavarian state government (Regierung von Unterfranken, 2021). The overarching goal of this strategy was to enhance the quality of drinking water across Bavaria by reducing nitrate pollution from intensive fertilization in the regional farming sector. The project successfully developed an agri-food value chain: Participating growers of baking wheat – numbering 35 at the time of the study – must skip the last nitrogen application before harvest, which can reduce nitrate leakage into groundwater by 25%–75%, depending on weather conditions. However, omitting the so-called "quality fertilization" reduces the protein level of the wheat by up to 1.5 percentage points to around 11%, which would normally result in lower sales prices. At the first stage of processing, the mills are contractually obliged to pay participating farmers the regular market price, which is normally reserved for quality wheat with a protein level of about 13%. Additionally, mills are required to store and grind the grain on separate processing rails. At the retail level, 36 artisan bakeries participated when the study was conducted. They must process and bake the flour separately and can then market the bread under the brand *Wasserschutzbrot*. A sufficient number of customers have been

TABLE 3 Case selection for the comparative analysis.

Case name	Product type	Sales channel	Sustainability claim	Number of actor groups	Coordination
Wasserschutzbrot	Pastry and bakery products	Artisan bakeries	Water protection	Five	Regional government
Landwirtschaft für Artenvielfalt	Various	Food retailers	Biodiversity protection	Five	Civil society organization
Waldgarten	Vegetables fruit eggs sheep products	Direct marketing	Various (e.g., biodiversity protection, animal welfare)	Two	Producer
Du bist hier der Chef	Milk	Food retailers	Animal welfare	Five	Private company and civil society organization
MoorFutures	Carbon certificates	Private certificate market	Climate protection	Four	State government

willing to pay a higher price for this product. Apart from protecting drinking water, the project also aims to raise awareness among producers and consumers and to promote regional development.

The second case, *Landwirtschaft für Artenvielfalt* ("farming for biodiversity") is a project jointly initiated by the nature and environmental protection organization World Wide Fund for Nature (WWF), the German organic farming association Biopark e.V., and EDEKA, one of the four leading food retailers in Germany. The Leibniz Center for Agricultural Landscape Research (ZALF) provides scientific advice. As part of the project, the scientists from ZALF developed a catalog of conservation measures intended to increase the diversity of wild species on areas of organically managed farms (Gottwald and Stein-Bachinger, 2018). At the time of our study, 60 organic farms in Germany were participating. The implementation of this conservation measures that are presented in the catalog as particularly effective in addressing biodiversity benefits was in some cases associated with higher costs compared to standard organic farming practices. The farms receive an additional certification that enables them to receive a higher price when selling their products through the sale channels of the established value chain. The retailer EDEKA guarantees the purchase of the various products of the participating farms and offers products for sale using a special logo.

The third case, *Waldgarten*, represents an organic farm located in the Prignitz region of Brandenburg in Northeast Germany (SoLaWi Waldgarten, 2021) that operates a community-supported agriculture (CSA) finance and marketing model (Fomina et al., 2022). The farm exists since the mid-1990s and is run as a CSA since 2012. Since then, an increasing part of the products (e.g., vegetables, fruit, chicken, and sheep products) is marketed through the CSA structure. In addition, other channels such as direct marketing are also used, although their share is steadily decreasing. Under the CSA structure, the farmer and the members of the CSA group jointly determine the budget for the upcoming year at an annual plenary meeting. Membership is obtained by purchasing one or more shares of the harvest per year. In anonymous bidding rounds, the members are increasing their offers until the necessary budget has been secured. This mechanism results in different prices being paid per share, which is considered as an expression of solidarity among the group members. At the same time, upfront financing hedges the risks of agricultural production, for example yield losses due to calamities, or widely fluctuating producer prices. The members' advance payments provide also a secure remuneration of the agricultural labor in exchange for a guaranteed share of the harvest. At the time of the study, one share cost 92 euros per month on average and included a weekly delivery of harvested products to nine self-managed pick-up points in the cities of Berlin and Potsdam. The production system combines arable farming and grassland (with mowing and grazing areas), and trees and shrubs (following the principles of permaculture). On this basis, *Waldgarten* claims to provide multiple sustainability benefits in addition to food production, for example, contributing to biodiversity protection through the abandonment of chemical-synthetical methods of crop protection, soil protection and increased water retention capacity through enhanced humus formation, or animal welfare through extensive grazing.

The fourth case, *Du bist hier der Chef* ("You are the boss here"), is a brand aiming to "give control over their food back to consumers" (Du bist hier der Chef, 2021). The brand describes itself as a "consumer initiative",[1] as it develops, produces and markets agricultural products on the basis of votes by consumers. The initiative acts as a broker. Through an internet-based consultation tool, interested members of the public (prospective customers) "vote" on specific production conditions of pre-selected agricultural products (e.g., the type of feed, standards for animal husbandry, price to be paid to the farmer), which are explained with indicative costs. Based on the results, the broker determines a product profile with criteria and prices (producer price and final sales price) and looks for agricultural producers, processors and retailers willing to produce, process and market the conceived product. Between the launch of the initiative in Germany in June 2019 and the time of our study, characteristics of one product (milk) were determined, which subsequently went on sale under the initiative's brand logo in various outlets of several food retail chains. With the selected characteristics for fresh milk, the initiative claims to contribute to more animal welfare as the cows are fed predominantly with fresh fodder, spend more than 4 months on pasture, and have increased opportunities for physical movement and social contact compared to legal standards. At the time of the interviews, the initiative planned to add more agri-food products (such as eggs and potatoes) to the portfolio.

1 The idea of the initiative originated in France, where consumer-created products have been successfully marketed in food retail under the consumer brand "C'est. qui le patron?!" since the end of 2016.

The fifth case, *MoorFutures*, represents a brand for carbon certificates offered on the voluntary carbon certificate market. The project was developed by what was then the Ministry of Agriculture and Environment in the German state of Mecklenburg-Vorpommern in collaboration with the University of Greifswald (Ministerium für Landwirtschaft und Umwelt Mecklenburg-Vorpommern, 2017). The project was implemented by the public settlement company of the state of Mecklenburg-Vorpommern (Landgesellschaft Mecklenburg-Vorpommern mbH). The general goal of the project is to harness the potential of rewetted peatlands to reduce CO_2 emissions. Revenue from the sale of *MoorFutures* is used to fund projects to rewet peatlands that have been drained for agricultural or forestry use. In addition to emission reduction, the regeneration of peatlands is expected to contribute to the protection of further ecosystem services, for example, in the field of water regulation and biodiversity protection (Joosten et al., 2013). Since the brand was established in 2011, three rewetting projects have been implemented in the state of Mecklenburg-Vorpommern (Polder Klieve, Kamerunwiese, Gelliner Bucht). In addition, the federal states of Brandenburg (in 2012, project Rehwiese), Schleswig-Holstein (in 2014, project Königsmoor) and Lower Saxony (in 2020, pilot project Seemoorwiesen) acquired licenses to use the brand. At the time of writing, *MoorFutures* projects covered an area of 130 hectare. The projects are accompanied by research projects from regional scientific institutions, which carry out the monitoring, for example, evaluating the emission reductions. Certificates can be purchased by individuals, companies or institutions to voluntarily offset emissions. The price is based on the costs required to avoid one ton of CO_2, which includes the costs for project planning and approval procedures, possible compensation to land owners, construction and monitoring of the climate impact.

3.3. Data collection and analysis

To complement the findings from the desk research, we conducted two sets of semi-structured interviews: with the persons identified as the coordinator in each of the five cases, and with six experts on sustainable agri-food value chains. The five coordinator interviews were carried out by two of the authors between 17th September and 11th October 2020. They lasted between 50 and 110 minutes. The aim of the interviews was to corroborate the information obtained in the desk research. A special focus was set on the governance arrangements in the respective value chain and trust-building mechanisms. The interview guideline was structured along four thematic focal sections (for a translated version of the interview guideline, see Supplementary material B1). First, we asked for general information about the history of the project, initiative or brand, its functioning, and the actors involved. The second section addressed the sustainability claims made and the measures implemented in order to deliver them. Based on the conceptual considerations on governance activities and trust, sections three and four of the interview guideline focused on the design of coordination activities and the strategies used in the respective value chain to build trust. The interviews were recorded and fully transcribed. The raw data were analyzed by two of the authors, using a computer-assisted qualitative data and text analysis program (MAXQDA) along a unified coding system that included both deductive and inductive codes (for a translated version of the coding system, see: Supplementary material B2). In the first round of coding, information on the value chain and claimed sustainability attributes was identified. The second round of coding focused on statements regarding coordination activities. This procedure made it possible to extract the key statements from the five interviews into a uniform system and then compare them. For the comparative analysis, we assigned each of the identified coordination activities in the five cases to the different sources of trust (see Section 2). The results of the data analysis were iteratively discussed and interpreted among the team.

The six interviews with scientists and experts from administration were conducted by two of the authors in order to discuss and validate the results of the comparative case analysis. They took place between 14th December 2020 and 11th January 2021 and lasted between 60 and 100 min. A second semi-structured interview guideline was developed to ensure that the earlier findings from the project were systematically discussed and that the experts had sufficient opportunity to express their own considerations. The guideline included three main thematic blocks: sustainability in agri-food chains; trust-building governance arrangements and activities; and policy interventions (for a translated version of the interview guideline, see: Supplementary material B3). Transcripts of the full interviews were analyzed by two of the authors, using MAXQDA along a uniform code system (for a translated version of the coding system, see: Supplementary material B4). In a first round of coding, the statements on sustainability-based value chains were evaluated in order to arrive at a consolidated definition of the concept. The second round focused on the responses to our findings regarding trust-building governance activities. In the third round, the experts' statements about necessary support and assistance were evaluated. This procedure allowed us to extract the relevant statements of the six experts into a uniform system. As with the first set of interviews, the results of the data analysis were iteratively discussed and interpreted among the members of the team.

4. Findings

4.1. Design of the coordination activities

In the first case, *Wasserschutzbrot*, the initiative for establishing the sustainability-based agri-food value chain originated from the Bavarian state government. In order to implement the measures decided at the state level, the district government of Lower Franconia, a subordinate authority of the federal state of Bavaria, appointed an administrator as project coordinator. The selected coordinator had professional experience in the agricultural administration and was well connected in the region. To initiate the project, the coordinator approached selected farms, mills and bakeries known from other professional and personal contexts to explore their interest in participating in the new value chain and to discuss the conditions for a possible cooperation. Further participants were acquired through the establishment of personal contacts by the project coordinator and already participating farms, mills and bakeries. The rules were developed and formulated during a participatory workshop facilitated by the project coordinator, resulting in four criteria for each stage of the value chain, now available online (Regierung von Unterfranken, 2021). All project partners commit to the implementation of these rules by signing a declaration. The coordinator serves as a networking and coordination hub. Network meetings are organized twice a year,

often combined with a visit to a participating mill or farm. The project coordination also carries out educational work with schools and centers for adult education (for example, providing learning materials and organizing informational events and excursions). A professional communication service provider designs information material, for example signboards for display at participating farmers' fields, flyers and commercials for the sales outlets. Participating value chain actors have specific documentation obligations, for example on processing quantities. These are controlled by the independent Research Institute for Organic Farming (FiBL) which also provides technical advice for the project coordination. If a violation of the established criteria is detected, the project coordination issues a written warning. The sanction for repeated violations is exclusion from the project and the value chain, and any project-related information materials (field boards, flyers, displays) must be returned.

The project *Landwirtschaft für Artenvielfalt* was initiated by the then director of the organic farming association Biopark e.V., who approached representatives of WWF and EDEKA to jointly develop the project framework and objectives. Using his personal contacts, he also recruited a number of organic farms to participate in the early stages of project development and to give feedback on the outlined project. To date, a prerequisite for participation in the project on the part of the farmers is membership in an organic farming association. To secure scientific expertise in nature conservation, the Leibniz-Center for Agricultural Landscape Research (ZALF) was included, especially advising on the constantly evolving rules for conversation and land management practices. Participating farmers receive advice in selecting and implementing nature conservation measures tailored to their farm and natural conditions. As part of the project, 12 advisors were specifically trained for this purpose. Cooperation of the value chain actors is facilitated by a coordination framework and individual cooperation agreements. An important component of the project is the communication of the conservation measures by means of a project website, a product logo, QR code tracking tools on the products and farm signboards and posters for direct marketing. Compliance with the criteria and implementation of the measures is verified during the annual inspection by the organic farming associations. Subsequently, each farm receives follow-up consultation during which the conservation measures are jointly reviewed and optimized. In case of violations of the rules, a farm can be excluded from the project, thereby losing the possibility to market their products with the project logo and through the project's sales channels.

Waldgarten was initiated by a farm manager in search of new marketing channels. He established a CSA structure for parts of the farm's products with the aim to develop a producer-consumer community, building on existing contacts with consumers from direct marketing. Objectives and concrete rules are formulated in an ongoing process between the producer and the members of the CSA, which comprises various formats, in particular an annual plenary meeting (which includes the bidding round for next season's shares), continuous thematic working groups and three to four joint farm visits per year. The agreed framework conditions of the producer-consumer community are laid down in a 10-point plan, which, along with the specified monetary contribution and the acquired share of the harvest, becomes the subject of an annual contract between the farmer and each individual member. The 10-point plan sets out general commitments among the CSA members that can be adapted during the annual plenary meetings. The CSA is based on the farm's operation in accordance with the requirements of an organic farming association, which is verified by the organic farming inspection body (organic certification). In addition, members of the CSA can convince themselves of the farm's compliance through direct exchange with the producer within the mentioned formats.

In the case of *Du bist hier der Chef*, the value chain is coordinated by a company and an association registered in Germany. The association is responsible for overseeing the consumer initiative and serves as a platform for networking. Responsibility for product development, contracting partners and marketing lies with the company. Any person can become a member of the association for a symbolic fee of 1 euro. In the example of the milk product, possible criteria and prices were developed by the company, involving potentially cooperating farmers and dairies. The final decision on production conditions was made by online voting, organized by the association. The rules for the milk include, *inter alia*, organic production, animals grazing on pastures, a producer price of 0.58 euros per liter (fixed for 3 years), and sustainable packaging that is climate-neutral through emissions-offsetting (Du bist hier der Chef, 2021). The selected criteria are stipulated in a product brief (*Pflichtenheft*) which forms the basis for the contractual agreements of the company with the farms, dairies and food retailers and must be implemented by all contractual partners. Compliance is monitored by an external auditing institute based on documentation of quantity flows and prices (for example, delivery bills). In addition, farm and dairy visits are offered to association members. At the time of this study, all 15 participating farms were members of an organic farming association, which entails annual controls under the framework of the organic farming regulation. The sanction mechanism in case of non-compliance with the specified criteria is non-payment.

In the fifth case, *MoorFutures*, the initiating and coordinating Ministry of Agriculture and Environment in the German federal state Mecklenburg-Vorpommern could build on positive experiences with a previous reforestation project. The Ministry aimed to create emission certificates for rewetted peatlands. For this purpose, the University of Greifswald developed a standard which is based on the internationally used Verified Carbon Standard. Besides this standard, the planning procedures foreseen under water protection legislation provide the legal basis for the rules formulated during the development of the trademark (Ministerium für Landwirtschaft und Umwelt Mecklenburg-Vorpommern, 2017). The implementation of the projects in the state of Mecklenburg-Vorpommern is coordinated by the state-owned public settlement company and includes the contract negotiation with land owners (land register entry of the water level to be tolerated) as well as the implementation of the construction measures by the state-owned construction companies. There are also awareness-raising measures, for example, information events and publications conducted by the Academy for Sustainable Development in Mecklenburg-Vorpommern and the Greifswald Mire Centre. Knowledge exchange between projects is supported by a cross-state project working group. The projects are subject to scientific monitoring by academic institutions in the respective federal states to ensure that the intended emission reductions have actually been realized (Couwenberg and Michaelis, 2015). If the emission reduction promised with the sale of the certificate is not achieved (which has not occurred so far), the shortfall has to be matched by purchasing carbon credits from other sources.

4.2. Formation of trust through the design of the coordination activities

The comparative analysis of the five cases has found considerable differences in the coordination activities regarding rule making, adoption, implementation, monitoring and enforcement. We now turn to the effects of the coordination activities on the formation of trust. As Table 4 shows, the coordination activities address the four types and sources of trust distinguished in Section 2.3 in different ways.

In *rule making* (agenda setting, defining the goals, and negotiating and formulating the concrete rules), trust was primarily established through the involvement of governmental institutions, scientific advice and civil society actors. These strategies addressed *dispositional trust*. In addition, participatory procedures either in criteria development or in decision-making on production and processing strengthened procedural legitimacy and thus *procedural trust*. Furthermore, personal contacts and recourse to shared values, identities and networks served to build on and further establish *affinitive trust* between the various actors involved. The coordinating actors had great importance in creating trust among all members of the value chain. In the five cases, the coordinating role was filled by a person who acted on behalf of a company or a government agency. In all cases, personal credibility and networking abilities were decisive for the establishment and maintenance of trust within the value chain

TABLE 4 Comparative analysis of coordination activities and the addressed sources of trust.

	Wasserschutzbrot	Landwirtschaft für Artenvielfalt	Waldgarten	Du bist hier der Chef	MoorFutures
COORDINATION ACTIVITIES					
Rule making					
Agenda Setting	Governmental institution	Private actor (farming association)	Private actor (farmer)	Private actor/civil society	Governmental institution
Determining the objectives	Governmental institution	Various value chain actors	Participatory (producer-consumer)	Private actor/civil society	Governmental institution
Negotiating/drafting rules	Participatory (value chain actors)	Research institute	Participatory (producer-consumer)	Participatory (consumers)	Research institute
Adoption					
Adopting the rules	Contractual obligation	Contractual obligation	Contractual obligation	Contractual obligation	Contractual obligation
Imposing the rules	Networking, public relations	Public relations, research	Networking	Public relations	Public relations, research
Implementation					
Implementing measures	Training and qualification	Training and qualification	Networking	Networking	Networking
Monitoring					
Testing, inspecting, auditing	Research institute	Organic inspection, advisors	Networking, organic inspection	Organic inspection, networking	Research institute
Certifying		State seal, private certification	State seal and private certification	State seal and private certification	
Documenting	Research institute, governmental institution		Participatory (producer-consumer)	Private actor/civil society	Research institute, governmental institution
Enforcement					
Sanctioning	Written warning, exclusion	Withdrawal of certification, exclusion	Leaving/exclusion of the community	Consequences of non-fulfilment of contracts (e.g. non-payment)	Compensation
SOURCES OF TRUST					
Rule making					
Agenda Setting	Trust in institutions	Shared values and identities	Trust in people	Trust in institutions	Trust in institutions
Determining the objectives	Trust in institutions	Trust in institutions	Shared values, identities, networks	Procedural legitimacy	Trust in institutions
Negotiating/drafting rules	Procedural legitimacy	Trust in institutions	Procedural legitimacy	Procedural legitimacy	Trust in institutions

(Continued)

TABLE 4 (Continued)

	Wasserschutzbrot	Landwirtschaft für Artenvielfalt	Waldgarten	Du bist hier der Chef	MoorFutures
Adoption					
Adopting the rules	Procedural legitimacy, transparency	Procedural legitimacy, transparency	Procedural legitimacy, transparency	Procedural legitimacy, transparency	Procedural legitimacy, transparency
Imposing the rules	Shared experiences, networks	Information on expected benefits	Shared experiences, networks	Information on expected benefits	Information on expected benefits
Implementation					
Implementing measures	Shared values	Shared values	Shared experiences, networks	Shared experiences, networks	Shared experiences, networks
Monitoring					
Testing, inspecting, auditing	Information on expected benefits	Trust in institutions	Shared experiences	Shared experiences	Information on expected benefits
Certifying	Trust in institutions	Information on expected benefits	Trust in institutions	Information on expected benefits	Trust in institutions
Documenting			Shared experiences, networks	Trust in institutions	
Enforcement					
Sanctioning	Procedural legitimacy, fairness	Procedural legitimacy, fairness	Procedural legitimacy, fairness	Procedural legitimacy, fairness	Procedural legitimacy, fairness

relationships. Dispositional and procedural trust were important mainly for outside credibility towards customers and the public, while affinitive trust was significant for relationships inside the value chain, supported by procedural trust to reassure participants that they would be treated fairly.

For *rule adoption and implementation* in the value chain, contracting was the most important strategy to build trust in the procedures and processes, primarily addressing *procedural trust*. Value chain actors in all five cases made great efforts to provide and disclose information, for example, on the rules and criteria (for example, catalogue of services and criteria, specifications, 10-point plan). In addition, other types of trust were addressed through various adoption and implementation activities. For example, meetings and farm or processing plant visits aimed to build networks and to create shared experiences as dimensions of *affinitive trust*. Education and training measures such as additional conservation qualification or consulting services as well as public relation activities were carried out in order to facilitate the development of shared norms and values, primarily addressing the formation of *affinitive trust*. Finally, the strong emphasis in two cases on accompanying research and scientific advice in providing information on the expected benefits can support the activation of *rational trust*.

The value chain designs varied greatly with regard to the *monitoring* of the adopted rules. On the one hand, building on well-established control and certification systems or scientific monitoring facilitated the provision of information about the realization of expected benefits, which in turn allowed to communicate the value proposition credibly. These activities addressed *rational trust*, supported by *dispositional trust* in established control institutions. The importance of scientific monitoring, especially in the development of criteria and their monitoring is associated with two key challenges: first, the measurement of sustainability-related value chain features, which is often discussed controversially, and second, communication of the monitoring results. Furthermore, various activities in the five cases aimed to strengthen compliance through shared experiences, for example visits to farms and processing sites. Such opportunities for personal inspection appeal to *rational trust* while the interaction could also contribute to *affinitive trust*.

In *rule enforcement*, the most important strategy for trust-building in all cases was ensuring perceived legitimacy and equal treatment in case of infringement. Non-compliance with the adopted rules regularly led to exclusion from the value chain, sometimes after written warnings. One case (MoorFutures) contained rules about compensation in case of insufficient performance. These activities addressed primarily *procedural trust*. The sanctions are important to reassure all participants as well as potential customers and the public that delivery of the value proposition is taken seriously. Even in smaller value chains, where compliance might be supported by social control and feelings of social connectivity, formalized systems of rule enforcement are necessary to ensure transparency, participation and fair treatment as dimensions of *procedural trust*.

4.3. Developing trust capacities

The analysis of trust formation through coordination activities found that the design of governance arrangements considerably affects the formation of trust along all stages of the agri-food value chains. Based on the comparative analysis of the five case studies, we mapped the various resources used by the value chain actors onto the sources of trust types (see Figure 1).

Addressing each of the sources of trust requires different capacities. In the five cases studied, building *dispositional trust* involved pre-existing personal contacts with relevant actors in the

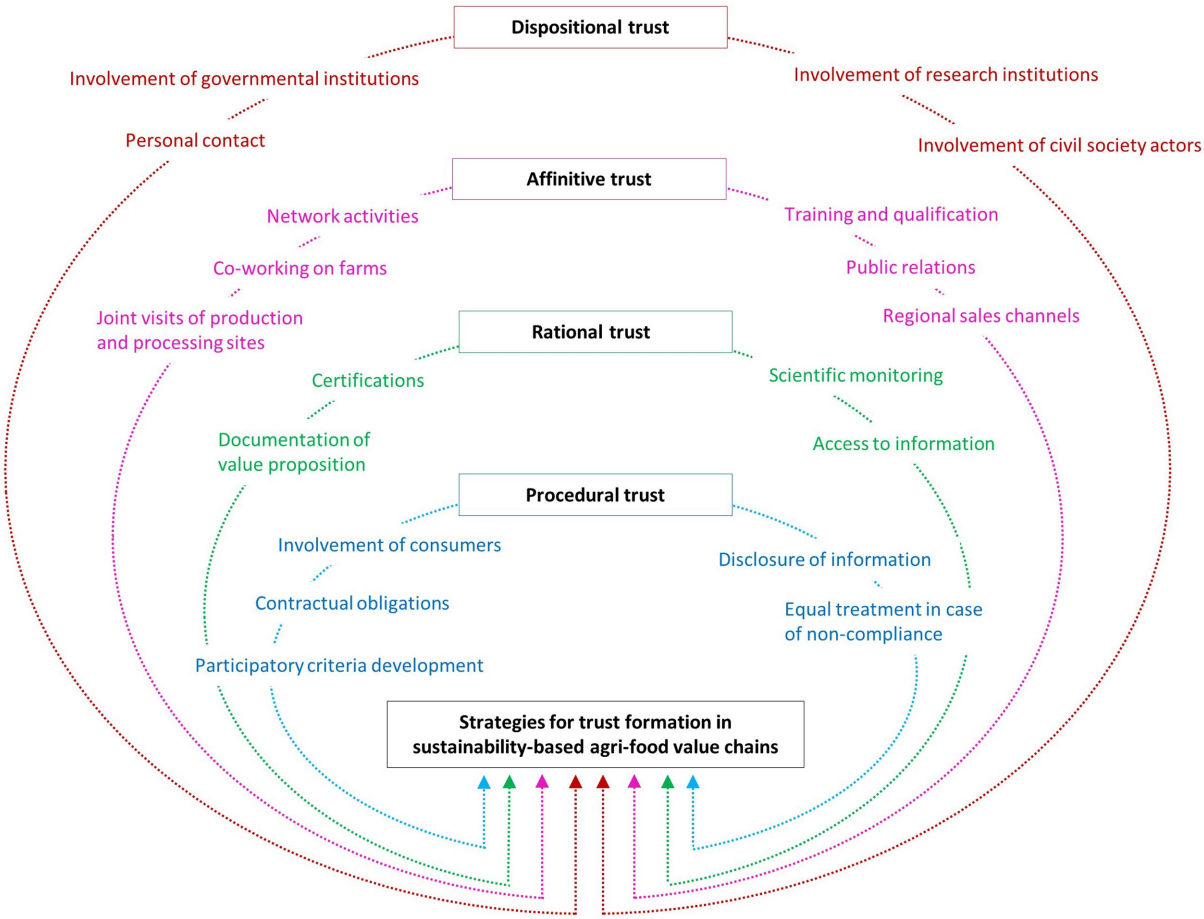

FIGURE 1
Trust capacities in agri-food value chains. Own representation based on *n*=5 case studies.

value chain and the ability to involve government institutions, scientific institutions and civil society actors. Associated challenges are the availability of well-connected persons with relevant networks, and access to institutions with epistemic or institutional authority. Building *affinitive trust* required the capacity of value chain actors, in particular the coordinator, to tap into the social connectedness of actors along the value chain, potential customers and the public. Whereas public relations activities might go some way, the five case studies found numerous collaborative activities which also served to strengthen affinitive trust by building shared values and experiences. While significant financial and personnel resources might be needed to secure affinitive trust, reputation, that is, the perceived integrity and benevolence of individuals, is an indispensable resource that cannot be substituted by financial means. Addressing *rational trust* required the capacity to credibly communicate expected costs and benefits. This often involved recourse to the capacities of third parties, for example through independent certification or external monitoring. New technologies such as QR codes can facilitate access to relevant information, thereby strengthening transparency. However, establishing such systems can incur high costs for the technology and the certification. Addressing *procedural trust* required cognitive and organizational capacities to plan and coordinate the various activities along the value chain. Analytical and social capacities were needed to co-develop rules and procedures which ensure fairness and transparency. Legal skills were required to formalize them in a reliable way. At a more abstract level, specific personnel resources are necessary which can be acquired if financial resources are available. Overall, the analysis shows that a broad range of different capacities was required in each case to ensure the trust needed at different levels to enable value chains based on sustainability claims.

5. Discussion

In this paper, we have analyzed the design of coordination mechanisms in five sustainability-based agri-food value chains in Germany to understand how their governance arrangements address the formation of trust. The selected cases were agri-food value chains based on claims that they contribute to sustainability merits, for example, the protection of biodiversity or environmental resources. Since such process claims cannot be verified by the consumer at the point of sale or by intermediate actors along the value chain, the ensuing information asymmetries are constitutive for credence goods. As a consequence, governance arrangements are required that enable trust in the veracity of the sustainability claims along the entire value chain. The selection of agri-food chains in Germany implies that their activities were embedded in institutional, political and cultural context conditions with relatively high levels of generalized trust (World Values Survey, 2022). Keeping in mind these limitations, four reflections emerge from our results that can contribute to broader discussions on

the governance of agri-food value chains and their possible contribution to transforming food systems towards more sustainability.

First, our analysis of agri-food value chains based on sustainability claims found that the actors involved in the coordination activities, including the making, adoption, implementation, monitoring and enforcement of rules, had backgrounds in the private, public and civil society sector. This finding resonates with the emerging research on "hybrid governance" arrangements in agri-food value chains (Verbruggen and Havinga, 2015), which are characterized by an interplay between private, public and civil society actors within the governance function (for example, participatory approaches in rule making or the delegation of monitoring to external control bodies or research institutes). Our results also confirm previous studies that have highlighted the importance of private standards in combination with third-party certification (Fulponi, 2006; Maloni and Brown, 2006), particularly to address negative externalities such as environmental degradation (Oosterveer, 2015). We also found support for claims that civil society actors are increasingly involved in the development of private standards since they can enhance the legitimacy of various claims (Raynolds, 2012).

Second, the results of the comparative case analysis show that the design of governance arrangements considerably affects the formation of trust along all stages of the agri-food value chains. Our findings indicate that a broad range of governance activities is used to activate different sources of trust. This observation is in line with earlier studies which emphasize the multidimensionality of trust (Stern and Coleman, 2015). Demonstrating the importance of all four different sources of trust in agri-food value chains – dispositional, affinitive, rational and procedural trust – provides a more nuanced account of the role of trust in such settings, particularly in connection with sustainability claims. While previous studies distinguished between different objects of trust as either interpersonal or institutional trust (Kjærnes, 2006; de Vries et al., 2019), or between different functions of trust as prerequisite for cooperation and coordination (Hanf and Dautzenberg, 2006; Mankad et al., 2017; Dania et al., 2018), our approach emphasizes the formation and importance of various sources of trust. This perspective embraces the relevance of the specific trust context and its dynamic (de Vries et al., 2022). While these contexts have often been understood primarily in geographical terms (either local or global), our findings suggest that the context can also be analyzed through the lens of the specific design of the governance arrangements and how it relates to sources of trust as part of the context of the value chain.

Third, the findings regarding the variegated governance activities with their impact on trust formation point to an important link between the development and maintenance of sustainability-based agri-food value chains and actors' capacities. Addressing each of the sources of trust requires different capacities. The analysis of the five cases found that different strategies were used to built these capacities, including the involvement of trustworthy individuals and institutions, creation of social connectedness, independent monitoring and certification as well as process organization. We use the term "trust capacities" to describe the cognitive, normative, material and social resources that can be used to form and maintain trust. These trust capacities are essential for the development of transformative food value chains since they facilitate the coordination of activities and the delivery on sustainability-related value propositions, thereby enhancing income and sustainability. The five cases presented here emphasize the crucial role of the actor with the coordinating function in the value chain. This observation resonates with previous studies which have highlighted the importance of leadership, entrepreneurship, innovation, knowledge and learning capacities on the development of sustainability-based agri-food value chains (Peterson, 2009). Lack of such capacities among value chain actors may be compensated by specialized consultants ("value chain developers") who act as "facilitators who support collaboration among value chain partners" (Braun et al., 2022). Our findings show that in hybrid governance arrangements, value chain developers can emerge from either the private, public or civil society sector.

The final reflection concerns the potential of agri-food value chains that are based on sustainability claims to contribute to a transformation of food systems. While it was not the focus of this study to assess the contribution of the five cases to more sustainable agri-food value chains, the governance perspective points to their limitations. Sustainability problems in the agri-food system result from negative external effects, that is, the private costs of production, processing, transport, retail, consumption, and waste do not reflect the full economic costs. This is a systemic problem. Harnessing private willingness to pay a higher price for products with enhanced sustainability features will not be sufficient to fully address the externalities problem. Such products necessarily address prime niche markets against the background of standard products with (at least perceived) lower sustainability (Chiriacò et al., 2022). Even worse, there is a paradox: The lower the general perceived sustainability standards in the agri-food system, the higher the market potential for products based on sustainability claims (van Doorn et al., 2021). Hence, the emergence of such value chains depends on a perceived gap between the sustainability of standard products and "sustainability products". Their success is as much an indicator of underlying sustainability problems in the broader food system as it might be a harbinger of a pending sustainability transformation. The latter would rather require a systematic internalization of negative externalities through a combination of regulatory and financial instruments (for example emission standards and carbon emission trading) along with a systematic remuneration of positive externalities through effective and efficient support policies (Pe'er et al., 2020; Feindt et al., 2022). It is unlikely that the externalities of agri-food chains will be fully internalized through consumer choices.

6. Conclusion

This study set out to examine how governance arrangements address the formation and maintenance of trust in agri-food value chains that are based on sustainability claims. Using a comparative analysis of five cases in Germany, we found that the design of governance arrangements was linked to the formation and maintenance of trust along all stages of the food value chains, and that variegated governance activities addressed different sources of trust: dispositional trust, affinitive, rational and procedural trust. Addressing each of these sources of trust required different capacities. These "trust capacities" are in general essential for the development of agri-food value chains since they enable actors along the value chain to coordinate their activities and to deliver on sustainability-related value propositions, thereby creating income and sustainability benefits. Whether such value chains can have transformative effects depends on the broader economic conditions. If sustainability claims mainly serve to activate higher willingness to pay, they rely on a relatively low level of perceived general sustainability of standard products.

This research contributes to a better understanding of trust development and its interrelationship with governance arrangements in value chains. Empirically, we add to the literature on the coordination and functioning of agri-food value chains built on special sustainability merits. The focus on the impact of governance arrangements on trust formation in sustainability-based agri-food chains contributes to a better understanding of the capacities of food systems to undergo a transformation towards sustainability.

The analysis of governance arrangements and trust capacities in agri-food value chains resonates with broader discussions on food systems, which highlight the need for developing their capacity to adapt and transform in response to environmental, social and economic threats in the 21st century (Ericksen, 2008; Meuwissen et al., 2019, 2022; van Bers et al., 2019). Our study helps to understand how the design of governance arrangements may affect the formation of trust and which capacities are required in order to establish and maintain them. Various coordination mechanisms can generate a higher willingness to pay in sustainability-based agri-food value chains. These observations have important implications for governancen practice. If we expect such value chains to become frontrunners of a sector transformation towards sustainability, policy strategies should be geared towards the creation of enabling frameworks. Policies such as the CAP of the EU should then pay more attention to agri-food chains, not only to the remuneration of producers for more sustainable farming practices. The CAP contains a number of instruments that are suitable for promoting agri-food value chains with enhanced sustainability, such as support for producer organizations, investments, information and knowledge transfer, European Innovation Partnerships, or advisory services (Linares Quero et al., 2022). However, the distribution of the budget among the CAP policy instruments and their concrete design betrays a focus on income support for agricultural producers (Feindt et al., 2022; Grohmann and Feindt, 2023). The EU Farm to Fork strategy provides some promising elements in this regard. However, only implementation will show whether its "game-changing potential" is will be realised (Schebesta and Candel, 2020). But while financial instruments that support the collaboration and formation of variegated capacities of the value chain actors are important, they cannot cover all trust capacities. Credibility, broad networks and access to actors and institution with independent epistemic authority are indispensable. Furthermore, since commercial success of value chains based on sustainability claims depends on a background of perceived general low sustainability, their function in a sustainability transformation of the agri-food sector appears both ambivalent and confined. Our study therefore also contributes to a better understanding of the limitations of sustainability-based value chains towards a food system transformation.

The results of this study are unavoidably limited by decisions of our research design, from which we derive three directions for further research. First, the study has an exploratory character, confining the case selection to sustainability-based agri-food chains in Germany. An analysis of further case studies from other contexts would be beneficial in order to corroborate the findings and to possibly identify additional challenges and coordination activities. An extension to more countries or transnational agri-food value chains may reveal other governance arrangements and other strategies of trust formation due to different context conditions in these regions. A further methodological limitation results from the restriction to the investigation of successful examples of sustainability-based value chains. An investigation of failed projects in this area would be desirable. However, such cases are more difficult to identify and those affected are generally less willing to provide information than actors in successful projects. Second, the role of the state (including the EU) and its agricultural policies in supporting more sustainable agri-food value chains requires further research (Grant, 2022). In this context, linking the perspective of hybrid governance to the emerging literature on agricultural post-exceptionalism might be a promising line of inquiry (Daugbjerg and Feindt, 2017). An interesting point of departure would be the discussion of shifting power relations in post-exceptionalist policy arrangements (Attorp and McAreavey, 2020). Our study raises the question whether specific structural, economic or cultural factors enable some individuals or organizations to build trust capacities more easily than others. A third direction of further research points to the contribution of governance activities and trust capacity development on strengthening the resilience of agri-food value chains (Stone and Rahimifard, 2018). Further research should focus on the question of how the sustainability performance can be maintained when food prices are skyrocketing, squeezing out consumers' willingness to pay a premium for credence attributes. In times of accumulating risks and shocks, trust and trust capacities may contribute to ensuring robustness, adaptability and transformability of sustainability-based value chains.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

PG: conceptualization, methodology, data collection, data analysis, writing—original draft, review and editing, and visualization. VD: conceptualization, methodology, data collection, data analysis, and writing—original draft, review and editing. CK and PF: conceptualization, methodology, data analysis, and writing—review and editing. All authors contributed to the article and approved the submitted version.

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Supplementary material

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Walter Odongo,
Gulu University, Uganda

REVIEWED BY
Kevan W. Lamm,
University of Georgia, United States
Luis F. Goulao,
University of Lisbon, Portugal

*CORRESPONDENCE
Aicha Mechri
✉ aicha.mechri@hu-berlin.de

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The transformative value chain: rethinking food system interventions

Aicha Mechri[1]*, Markus Hanisch[1] and Hendrik Hänke[2]

[1]Centre for Rural Development, Faculty of Life Sciences, Humboldt-Universität zu Berlin, Berlin, Germany, [2]Sector Strategy, Knowledge and Learning Unit, Welthungerhilfe (WHH), Bonn, Germany

Food value chains (VC) are an integral part of food systems, and (VC) programs remain central in the work of development agencies. Despite their popularity among donors and their attempts to tackle food and nutrition security, poverty alleviation and environmental sustainability, food value chain interventions are at crossroads. The ongoing food system crisis has ultimately put a square emphasis on food as a nexus issue. The objective of this paper is to review the history and conceptual basics behind food VC development and to suggest changes in the way interventions are designed and implemented in order to face the current critical juncture of food systems. The paper reviews theoretical as well as empirical underpinnings of contemporary food value chain interventions. Three transformative concepts, i.e., system thinking, transformative capacity and strong sustainability, embedded within agroecological principals, are suggested to replace the traditional paradigm of the sustainable food VC development. A new, principle-based perspective on food value chain development, "the transformative value chain perspective," is proposed to ensure that future VC promotion contribute to the necessary sustainability transformation of our food systems.

KEYWORDS

food value chains, food system transformation, sustainability, agroecology, transformative value chain perspective

1. Introduction

Food systems worldwide are facing numerous challenges related to environmental hazards, food security and nutrition and social wellbeing (Caron et al., 2018; FAO, IFAD, UNICEF, WFP and WHO, 2021). Currently, most land degradation and loss of biodiversity can be linked to agriculture (IPBES, 2019), which is not only the greatest freshwater consumer (World Bank, 2022) but also generates more than 30% of all greenhouse gas emissions (IPCC, 2022). At the same time, more than 828 million people do not eat enough food (FAO, IFAD, UNICEF, WFP and WHO, 2022), around 3 billion people cannot afford healthy diets, and 2 billion people are overweight or obese (Webb et al., 2020; Stevens et al., 2022). Being major risks to human health, biodiversity, and climate, today's food systems are operating beyond planetary boundaries (Rockstroem et al., 2021; McKay et al., 2022), indicating they require substantial transformation (Sachs et al., 2021). Paradoxically, most of the world's poor and food and nutrition insecure are small-scale agricultural producers living in rural areas (Castañeda et al., 2018; Woodhill et al., 2022), despite targeted development cooperation for improved agricultural production, improved income-generating activities, better access to markets, and vertical integration in the Global South (Humphrey and Navas-Alem an, 2010; Stoian et al., 2016; Donovan and Poole, 2014).

Food value chains (VC) are integral to food systems and remain central in the food security, social justice, and environmental sustainability work of development agencies (FAO, 2015; AGRA and UNDP, 2020; Barrett et al., 2020; IPES-Food, 2020). Food VCs are promoted in many countries through bilateral and multilateral technical cooperation programs with the aim of increasing income for small farming enterprises, boosting employment, and improving regional food supply in target regions. Such programs support smallholder farms increase their agricultural production and income by, for example, supporting their market integration, ensuring jobs in processing, and ensuring a greater portion of value added from agricultural production remains in the region, especially in rural areas (Fan and Rue, 2020). Despite widespread recognition of pro-poor agricultural growth for increasing orientation towards sustainability goals (FAO, 2014; Schmidt et al., 2019), there is no evidence that food VC interventions deliver on the expected sustainability outcomes (Ton et al., 2011; Stoian et al., 2016; Mausch et al., 2020). Consequently, within the framework of development cooperation programs, two pressing questions arise:

(1) How can we ensure VC interventions are integrated in food system transformation agendas in the future?
(2) With regard to their transformative potential, how can concepts like strong sustainability, transformative capacity, and system thinking be integrated in VC interventions?

The aim of this paper is to outline how future VC interventions can contribute towards transforming food systems to achieve sustainability. The paper reviews the status quo in food VC development paradigms and their evidenced impacts, discusses some of the transformative concepts related to food system transformation, and proposes a transformative perspective on food VC design and implementation.

In Section 2, we explore theories and literature underpinning VC interventions in development contexts and, in Section 3, we discuss recent findings and thinking in sustainability and resilience research. Section 4 proposes a way of incorporating the new concepts into the systematic and holistic treatment of VC programs, producing a normative paradigm that we term the *Transformative Food Value Chain (TFVC)*. In Section 5, we provide some pathways for the future of food value chain interventions using the TFVC approach.

2. The value chain approach in international development cooperation

2.1. Origins and baseline concepts

The VC approach stems from and merges several theoretical strands, including agri-business and supply chain management, world-systems theory, and dependency theory (Porter, 1985; Hopkins and Wallerstein, 1986; Kaplinsky and Morris, 2001; Gereffi and Sturgeon, 2013). The origin of the VC approach for development contexts can be traced back to the French *filière* approach of VC analysis in the 1960s, Wallerstein's world-systems theory of the 1970s, and the value system introduced by Porter's competitive advantage theory in the 1980s (Porter, 1985). The filière concept was developed to study export products in former French colonies and gave specific attention to physical trade flows. Porter (1985) competitive advantage theory introduced a value system that enables identification of value addition through every step of the supply chain. In the 1990s, Gereffi and other scholars extended the focus beyond domestic products by framing global commodity chains and analyzing power relations in the coordination of globally dispersed, but interlinked, production systems (Gereffi and Korzeniewicz, 1994; Gereffi, 1994). The global commodity chain framework later evolved into what has become known as global VCs, reflecting a more dynamic view of chain governance (Sturgeon et al., 2008; Gereffi and Sturgeon, 2013). The global VC framework and literature on the global VC framework developed in the last two decades have been broadly used as a basis for donor-led VC interventions.

Following the 2008 release of the World Bank publication *Agriculture for Development* that focuses on agricultural growth, VC interventions regained momentum in agricultural development agendas. Within a large portfolio of tools and approaches, VC interventions emerged as the new development model for achieving the Millennium Development Goals and, later, the Sustainable Development Goals (Donovan and Poole, 2014; Stoian et al., 2021). The underlying idea is that a private-sector-driven VC development process would support inclusion of smallholder farmers in markets, thereby improving livelihood security and guaranteeing a decent standard of living (Donovan and Poole, 2014; Stoian et al., 2021).

In agri-food development programs, the use of VC approaches has especially been driven by growing demand for agri-food products, with a special focus on cash crops and specialty crops considered as having great potential for achieving both economic and social benefits (Humphrey and Navas-Alem an, 2010; Ricketts et al., 2014; Devaux et al., 2018). Over the last two decades, VC approaches have enjoyed widespread popularity among donors, including FAO, the German Ministry for Economic Cooperation (*Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung*: BMZ), the United States Agency for International Development (USAID), the Value Chain Analysis for Development of the European commission (EU) and development agencies such as the German Agency for International Cooperation (*Deutsche Gesellschaft für internationale Zusammenarbeit*; Taglioni and Winkler, 2016).

From a donor perspective, the primary goal of VC interventions has been so-called 'pro-poor growth' under the assumption that VC development with pro-poor growth objectives will help reduce poverty and eradicate hunger (Humphrey and Navas-Alem an, 2010; Springer-Heinze, 2018; Stoian et al., 2021). In addition to addressing pro-poor growth and smallholder-inclusion objectives, VC interventions have increasingly been employed to address sustainability objectives, for example, related to food and nutrition security (De La Peña et al., 2018; Gelli et al., 2020).

As an analytical framework, the VC concept has mainly been used to identify and map the actors, structures, and dynamics involved in VCs (Kaplinsky and Morris, 2001) with analyses focusing on the positioning of chain actors, the linkages between them, the distribution of value added along the chain, and opportunities for upgrading (Gereffi et al., 2001; Kaplinsky and Morris, 2001; Barrientos and Gereffi, 2011). In practice, donor-led VC interventions have tended to follow two common approaches: one focusing on individual junctions along VCs in governance structures and institutional environments (Ponte and Sturgeon, 2014) and the other taking a

firm-centric approach that promotes leading private-sector actors and their direct environment (FAO, 2015).

The VC approach for development assumes that the labor market acts as a central link between economic growth and its social impact. The underlying hypothesis is that faster economic growth leads to a larger number of people who will find work in the formal sector (Kaplinsky and Morris, 2001). The idea that integrating smallholder farmers into partnerships with agri-business firms can generate benefits for national economies, private investors, and livelihoods is at the core of VC interventions in development programs (German et al., 2020).

2.2. Integrating sustainability goals in VC development agendas: the example of FAO's sustainable food VC framework

Over the last two decades, VC approaches have incorporated sustainability concepts and the goals of the Millennium Development and Sustainable Development agendas of the BMZ, FAO, and USAID (Taglioni and Winkler, 2016). A good example of placing food VC development at the core of sustainable food systems with the goals of reducing poverty and food and nutrition insecurity is FAO's sustainable food VC (SFVC) development framework (FAO, 2014).

Conceptually, FAO's SFVC is based on a three-pillar sustainability model (see discussion in Section 3.2), with the underlying assumption that food insecurity is a symptom of poverty (FAO, 2014). According to this paradigm, households escape poverty when they have adequate financial resources, thereby creating additional demand for food supply. In turn, this demand helps drive competition between supply chains, thus decreasing prices. From this perspective, the objective of such interventions is not to preserve smallholder farming but, rather, to alleviate poverty by ensuring broad-based job creation, income growth, and wealth accrual. In particular, FAO (2014) stresses that supporting smallholder farming by means of value chain integration does not contribute to poverty reduction. Rather, the assumption is that trying to keep all smallholder farmers, and more particularly the poorest farmers, in farming and in rural areas may hinder agricultural development, large-scale poverty reduction and hunger eradication (FAO, 2014). Based on that, SFVC proposes that development efforts are focused on the most capable, driven and commercially oriented smallholder farmers. From this perspective, unsustainable food systems are a consequence of poor sector development and poverty. Therefore, poverty alleviation and food security are seen as benefits to be reaped from developing VCs into "agricultural growth engines" (FAO, 2014).

FAO's sustainable development paradigm exhibits most of the features common to the agricultural development processes in most countries of the Organization for Economic Co-operation and Development, including structural change reducing labor, agri-technical innovation and intensification, and social programs for the poorest rural households. The mechanisms driving the paradigm include higher returns on assets for entrepreneurial farmers, salaried incomes for the 70–90% of actors who will be forced to leave farming, and higher tax revenues for distribution to victims of disasters and the extreme poor. According to FAO (2014), SFVC development is intended to benefit farms and firms that "produce particular raw agricultural materials and transform them into particular food products that are sold to final consumers and disposed of after use, in a manner that is profitable throughout, has broad-based benefits for society and does not permanently deplete natural resources" (p. 7).

The FAO framework is based on a triple-bottom-line (TBL) concept of sustainability which identifies sustainability as a set of equally important economic, social, and environmental goals. These goals are presented as measurable outcomes that can be determined objectively. In this understanding, sustainability goals are not integrated but compartmentalized and additive, meaning that they are looked at separately using a variety of indicators, the total sum of the analysis indicating "sustainability." Moreover, there is a tendency to assume a "win-win scenario" where social and environmental goals reinforce economic gains. In particular, the FAO SVCD framework stresses that "social and environmental sustainability are themselves becoming sources of value creation and competitiveness. For example, a greener product image may represent a higher value to consumers and (positively) differentiate the product in the market" (FAO, 2014). Here, economic goals such as profit are depicted as the "main goal" of SVC development, and it is warned that the pursuit of social or environmental goals runs "the risk that […] VC development is confused with social support or environmental protection programs which are of a fundamentally different nature" (FAO, 2015). All in all, the FAO framework and the TBL is a "weak" understanding of sustainability and stands directly at odds with strong sustainability conceptions whereby society and economy are subsystems of the environment and urges to consider both the uncertainty and irreversibility of environmental destruction. Following this line, the integrity of ecological systems must be preserved, meaning that certain thresholds (planetary boundaries) must not be crossed. Setting these thresholds is not only a question of social and political preference but ecosystem resilience: the extent to which an ecosystem is able to recover from shocks and stress.

2.3. Impact of value chain development interventions on expected sustainability outcomes

As shown in the previous section, VC interventions have generally aimed at reducing poverty and eradicating hunger by means of pro-poor growth. Nevertheless, clear evidence of the food security or poverty impacts of such interventions is ambiguous or lacking (Mausch et al., 2020). To date, the most exhaustive review of VC impacts was conducted in Humphrey and Navas-Alem an (2010). Their review of 30 VC interventions revealed that the poorest often do not benefit from VC interventions because of their orientation to "winners" (better-off farmers), thus hindering reduction of average poverty levels and failing to address the most vulnerable as a target group (Humphrey and Navas-Alem an, 2010; Stoian et al., 2016). Similarly, an evaluation of agricultural VC interventions undertaken by German bilateral cooperation programs revealed that smallholders' successful participation in VCs depends on their access to a minimum level of resources before the intervention is applied and that resource-poor households did not benefit from interventions (Kaplan et al., 2016). Other studies have found a positive, but moderate, impact on producer prices and farmer incomes as a result of VC interventions but no positive impact on food security (Herrmann et al., 2018; Ebata and Huettel,

2019). Although the goal of increasing productivity through, for example, increased mechanization and integration of innovations at different VC stages, is at the heart of such interventions, they have paradoxically led to inefficiencies in the food system by, for example, increasing food losses or converting human food to animal feed (Benton and Bailey, 2019).

Moreover, there is little evidence of how such interventions support poverty reduction (Humphrey and Navas-Alem an, 2010; Ton et al., 2011; Höffler, 2020) and food and nutrition security (Gelli et al., 2020; German et al., 2020; Nicholson et al., 2021). Increasing challenges related to the sustainability of food systems ranging from environmental concerns to dietary, health, equity, power, and trade issues are raising doubts that the VC approach, at least in the ways it is currently promoted, is the appropriate instrument for holistically tackling sustainability challenges within food systems (Mausch et al., 2020).

Lack of evidence regarding the impacts of VC interventions is partly due to the complexity of the horizontal and vertical socio-technical structures forming VCs, which entail many actors intervening at different stages and pose challenges for assessment. It is likely that other structural problems, such as criminality or land tenure rights, can impact VC intervention outcomes (Mausch et al., 2020). However, as they are external to the influence of VCs, such factors make the linking of outcomes to interventions during planning and assessment problematic (Donovan and Poole, 2014).

The dearth of proven impacts can be explained not only by lack of evidence in impact assessments but also by an absence of sound statistical design in existing studies. Ton et al. (2011), for example, found that the impacts of VC interventions often rely only on anecdotal evidence. Despite awareness among practitioners of the importance of aggregated poverty impact assessments, no reference is made to national poverty levels or similar quantitative measures of well-being in most project monitoring systems (Höffler, 2020). More importantly, according to Mausch et al. (2020, p. 5), "the limited evidence on the impact of (VC interventions) VCIs further questions the underlying theories of change and impact pathways."

Despite these concerns, agri-food VC interventions have been important components of development cooperation projects and programs that have sometimes achieved success in different terms, with benefits to both farmers and commercial partners (Fan and Rue, 2020). The approaches and concepts underlying their design and implementation have changed over time and, hence, have become woven into many aspects of the sustainable VC agenda in terms of goal setting (FAO 2014b; Schmidt et al., 2019). However, the literature on evaluation of such interventions has revealed that there are many contexts where the success of individual supply chain projects has been limited and hampered by wider sectoral or food-system dynamics. More importantly, it has been found that many such interventions do not improve the overall performance or resilience of the agri-food sector they were aimed at, nor contribute to the sustainability of broader agro-food systems (Molenaar and Vorley, 2017; Borman et al., 2022).

In essence, the VC approach has been criticized as offering linear solutions and technical fixes to complex concerns, whereas a holistic perspective for tackling systemic, root challenges related to food system transformation is needed (Molenaar and Vorley, 2017; Mausch et al., 2020). In recognition of these shortcomings, the following section reviews new ideas about the basic underlying concepts of the VC approach and their capacity to inform reconceptualization of sustainable VC interventions.

3. Rethinking food value chain development: on food systems, strong sustainability, and transformative capacities

3.1. Food system thinking

One motivation for analytically and practically reaching beyond current conceptualizations of VC interventions is that the benefits derived from such interventions have generally not lasted over time, were not scalable, or were related to issues that are not to be decoupled from the sector that is targeted by the interventions.

For decisions on interventions into food VCs, sector development priorities are often already pre-defined in national development plans in accordance with national priorities (International Labour Office, 2015). While development agencies need to take these priorities into account, not all the prioritized sectors will target sustainability problems and food system transformation (Wieben, 2019). Analytically considering political preferences, wider implications of sector governance and institutions, and mapping relevant relationships and interdependencies between prioritized VCs, their alternatives, and the sustainability attributes of the overall food system must therefore become a prerequisite for policy dialog prior to the selection of food VC intervention activities (Schneemann and Vredeveld, 2015).

A natural point of departure for developing a holistic vision of the food VC approach is offered by the Sector Governance Framework (Molenaar and Vorley, 2017). The framework assumes that good sector governance is a much-neglected prerequisite for successful VC initiative, can provide better-targeted VC strategies and may even drive sustainability outcomes. This framework proposes to improve sector dynamics via a set of promising governance instruments (e.g., sector coordination bodies or sector platforms) that are identified, observed, and tested in empirical studies to improve important sectoral functions as well as typical VC features. The framework has been put in practice by development organizations and been applied to public policies for enabling living incomes in global agricultural value chains (Enssle et al., 2022). Strong stakeholder agency and participation are important components of this perspective (Molenaar and Vorley, 2017).

Food system thinking integrates this perspective but goes beyond sector governance by including food production and processing, socio-economic and environmental drivers, and food system outcomes and their interrelations (van Berkum et al., 2018; see Figure 1). Food system analysis centers the food supply system and distinguishes three levels for consideration: (1) food system activities lead to food system outcomes like availability, access, security, agency, health, and human behavior; (2) these outcomes affect the socioeconomic drivers of food system activities; and (3) the environmental drivers of food system activities. Food system thinking highlights interrelationships among food system components and encourages us to consider how modifications to individual components affect system balance; for example, food production enhancement programs must plan for repercussions across interrelated system components such as environmental or social

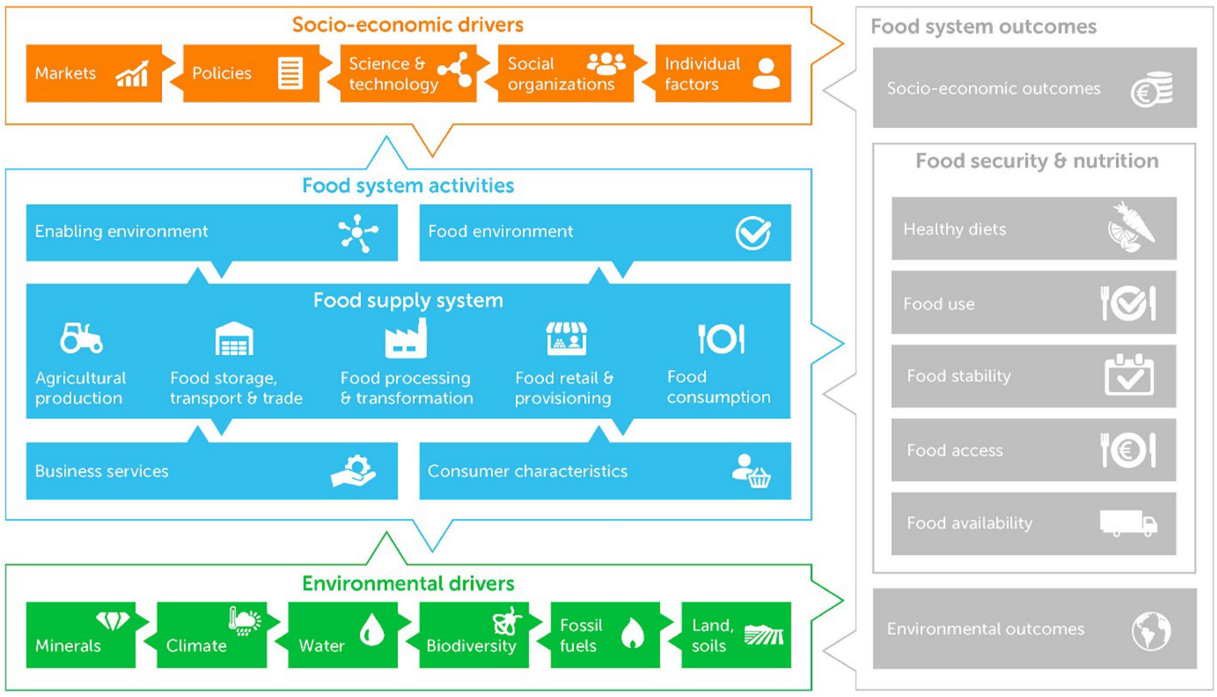

FIGURE 1
Mapping relationships within the food system. (Source: van Berkum et al., 2018).

damage/costs (van Berkum et al., 2018; de Adelhart Toorop et al., 2021). Moreover, a food system perspective accounts for non-linearity and food system vulnerability, promotes studies of food system component interactions, and accounts for externalities.

In view of the current state of global food systems, adaptation or radical transformation may be required to reach long-term local-to-global food system resilience. Innovations may happen at a technical, organizational, political or socioeconomic level. When prioritizing interventions, analysis of causes, effects, and circular relations between drivers and food system outcomes are prerequisites of food system thinking. However, adding analytical levels, sustainability dimensions, and aspects like adaptation and transformation may make setting priorities and entry points challenging.

In this regard, Borman et al. (2022) highlight that holistic "food systems thinking" requires actionable measures and propose that combining the sector governance framework (Molenaar and Vorley, 2017) with food system thinking could provide a useful multi-level analytical framework for sustainable food system transformation.

3.2. Strong sustainability

Considerations around VC interventions are also due to the complexity of the sustainability conceptualization underlying the current VC development approaches. Sustainability, once referred to as a "mobilizing concept" (Blowers, 1993, p. 5), has become a compromise-driven political, normative, and value-laden notion, generating discourses based on a variety of factors, including means of transition, agents of change, and the role of technology (e.g., Lele and Norgaard, 1996; Gibson, 2006; Bell and Morse, 2008; Gasparatos et al., 2008; Bond et al., 2012). The core of the sustainability discourse, which arose from broadly different schools of thought, has given rise to a variety of definitions with ambiguous theoretical foundations. As a result, at least 200 definitions of sustainability have been identified (Kates, 2011; Mark, 2013; Wu, 2013) and are commonly used. At the heart of this debate lies a fundamental cleavage between two dominants yet opposing archetypes, namely "weak" and "strong" sustainability (Daly, 1993). Weak sustainability, a model often illustrated through the "triple bottom line" (Elkington, 2018) or three-pillar models (see Figure 2) is based on substitutability of the three sustainability dimensions (economic, social, and environmental) and argues for allowing trade-offs, such as subsummation of environmental effects by economic goals (Gibson, 2006; Fracarolli Nunes et al., 2020). Advocates of the three-pillar model of sustainable VC development (e.g., FAO, 2015) argue that aspects of economic sustainability need to be prioritized because, it is believed, social and environmental goals of sustainable development may only be met after economic development goals are reached through trickle-down effects resulting from, for example, additional tax income and social and environmental redistribution of the benefits of economic development and growth (FAO, 2014). From this perspective, "manufactured" and "natural" capitals (Daly, 1993) are considered substitutable because no distinctions between the kinds of wellbeing they generate are made (Ekins et al., 2003; Neumayer, 2003, 2012). This model of weak sustainability has informed most manuals on VC intervention design (Donovan and Poole, 2014). For example, FAO's sustainable VC development approach places priority on economic growth by explicitly mentioning trickle-down effects and necessary trade-offs between sustainability dimensions and claims that "*in terms of environmental sustainability, the upgraded VC model should create additional value without permanently depleting natural resources*" (FAO, 2014, p. 25).

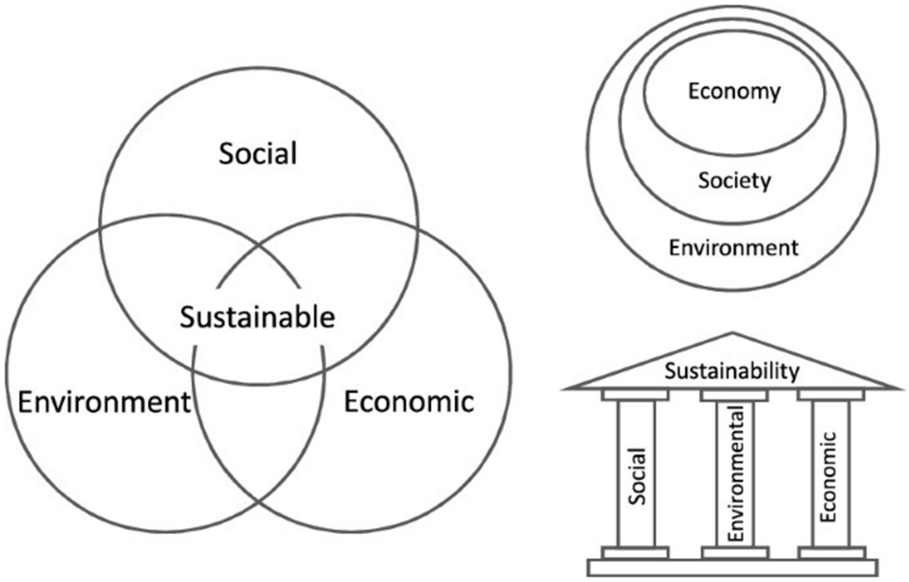

FIGURE 2
Conceptualizations of sustainability: Three pillar (left), triple bottom line (bottom right), and strong sustainability/nested systems (top right). Source: Purvis et al., 2019.

Additionally, the operationalization of sustainability poses numerous challenges because generating indicators based on value judgments is both analytically challenging and intrinsically political (Feindt, 2002; Stiglitz et al., 2008). While sustainability is recognized as being normative, its operationalization requires both explicit description of how it is understood as well as much stronger stakeholder involvement to guarantee agency (Molenaar and Vorley, 2017). Because the three-pillar model assumes that social, natural, and economic components are substitutable, misconceptualization may lead to political compromises favoring economic interests in sustainable development programs and environmental reductionism (Connelly, 2007). However, ongoing crises, increasing food and nutrition insecurity, loss of biodiversity, and increasing social injustice call for a radical change in conceptualizing sustainability towards social–ecological priorities and repurposing economic activities to safeguard natural resources and ensure the wellbeing of all societies, both current and future (Bonnedahl and Heikkurinen, 2018; Gliessman et al., 2019; Rockstroem et al., 2021). In reviewing how the triple bottom line concept and its derivatives have impacted sustainable development, even its architect, John Elkington, has recently warned about the risks of the triple bottom line and suggested a management concept recall: "I'm not sure it's going to be enough. Indeed, none of these sustainability frameworks will be enough, as long as they lack the suitable pace and scale—the necessary radical intent—needed to stop us all overshooting our planetary boundaries" (Elkington, 2018, p. 3). It is inarguable that human activities and their impact on earth system processes have triggered the overshooting of several planetary boundaries (Hickel and Hallegatte, 2022), indicating that treating the economy, society, and environment as interchangeable may to put humanity's safe operating space at risk (Rockström et al., 2009; Rockstroem et al., 2021; IPCC, 2022; McKay et al., 2022). Meanwhile, the strong sustainability paradigm, discussed below, holds that society and economy are subsystems of the environment and takes the uncertainty and irreversibility of damage occurring to the biosphere seriously (Daly, 1993).

3.3. Transformative capacity

A third motivation for reaching beyond today's VC intervention conceptualizations has to do with the notion of food system transformation and the need for placing actors—their knowledge about context and their interpretations of their environment, rights, value networks, and creative capacities—at the center of understanding agri-food system sustainability and development (Folke et al., 2009). Transformation can be described as a significant reordering that questions how a system can function differently if specific steps are undertaken (Meadows, 2008). More narrowly, transformation can be differentiated from resilience (associated with persistence) and adaptation (involving the notion of incremental change; Pelling, 2010; O'Brien, 2012; Brown, 2015). One framing of transformation in science and policy discourses highlights social-ecological transformation, a concept pioneered by researchers at the Stockholm Resilience Centre. Social-ecological transformation can result in novel emerging system properties, changes in critical system feedback (Chapin et al., 2009), and re-ordering of social-ecological relationships (Olsson et al., 2017). Moreover, any transformation typically involves unanticipated consequences that may worsen some conditions (Moore et al., 2014; Olsson et al., 2014). Resilience, in the sense of preserving system stability as well as observing transformation across levels of temporal or structural stability (Garmestani et al., 2009), involves various kinds of agency across system levels (e.g., learning, investment, conflict resolution, cooperation), resulting in complicated processes that cannot be addressed by single and simplistic interventions (Folke et al., 2016).

In order to achieve resilient outcomes, of transformative capacities need to be enhanced as a way to fundamentally rethink the necessary

changes to the current system (Ziervogel et al., 2022), The transformative capacity thinking highlights that systems and the behaviors of actors depend on resources, follow certain dynamics and, depending on the context, need to change fundamentally (transformation) or continuously (transition) to survive (Tendall et al., 2015; Ge et al., 2020). Transformative capacity thinking focuses on the context and what food systems with their actors can put into play to survive in the long term.

In view of crises, the concept of transformative capacity, as proposed in studies from the social-ecological system dynamics and resilience literature, provides a preliminary response for understanding food system actors' roles and capacities to better understand, initiate, and shape own interpretations of sustainability (Boyd and Folke, 2011; O'Brien, 2012; Wolfram et al., 2019). Borrowing from both theoretical and empirical strands of literature, transformative capacity defines the skills and system dynamics needed to re-conceptualize and create a fundamentally new system with new characteristics and new control variables defining it (Berman et al., 2012; Hölscher et al., 2018). Here, transformative capacity involves a potential level of human agency (Kofinas et al., 2013). Approaches for investigating food VC sustainability have used similar notions of "transformative capacity" (Campbell et al., 2018; Barrett et al., 2020; Herrero et al., 2020; Loboguerrero et al., 2020), but they remain focused on particular types of technology (El Bilali, 2019), the innovation "imperative" (Anderson and Maughan, 2021), and different socio-economic upgrading mechanisms (Gradin, 2016; Adetoyinbo and Otter, 2021). However, the transformative capacities of VC actors and how to gauge broader enabling conditions at the policy design stage have yet to be specified.

In the following paragraphs, we provide an interpretation of sustainable VC development that is based on the three transformative concepts discussed above: strong sustainability, system thinking, and transformative capacity. Our aim is to widen the scope of food VC interventions and programs in terms of the objectives pursued and in terms of capacity building and knowledge creation activities along future VC development interventions.

4. Discussion: applying the transformative value chain approach

The aim of this section is to provide a perspective on VC interventions, recognizing that the ways VC development influence food systems need to be fundamentally transformed if sustainability is the goal. The question at hand is not how to develop VC interventions into solutions for solving problems of universal dimensions. Rather, the question is how we can make sure future decisions on the design and implementation of VC interventions prevent the latter from, in effect, exacerbating the social, environmental, and economic sustainability problems within contemporary food systems. Building on our discussion in Section 3, in the next paragraph (Section 4.1) we propose and seek to justify three fundamental conceptual changes in the VC paradigms guiding contemporary food VC interventions. In Section 4.2, we discuss the way decisions about interventions in complex social ecological systems take place.

Our thesis is guided by the assumption that interventions at the level of the food supply system (van Berkum et al., 2018) will remain important components of international development cooperation programs. The guiding question is how future VC interventions at that level can meaningfully contribute holistically to the transformation of contemporary food systems. The following three hypotheses characterize the direction and the trade-offs to be considered when integrating new thinking into interventions at the VC level:

- Though VC concepts need to be further developed to address food system transformation, ultimately, measures must be broken down to actionable levels. In other words, decision makers and practitioners need to be able to focus and decide on interventions being applied to measures and food products (FAO, 2014).
- Given deepening food system crises, decisions on VC interventions as part of development cooperation programs will have to increasingly acknowledge and pursue an even wider spectrum of objectives related to the *transformation of food systems towards sustainability*. As we showed in Section 2, adding sustainability objectives to VC intervention projects obscures impact assessment on the basis of weak indicators and criteria. This may further add complexity to the methods needed to control intervention processes when decisions about interventions are being made.
- Because food system transformation is an open-ended, multi-objective, and context-specific process, active engagement of actors along the VC is a key prerequisite for co-creation of knowledge. Methodologically, this includes the intensification of stakeholder dialogues and participation in development cooperation for process monitoring, reaching consent, and triggering collective action.

In the next section, we propose areas of fundamental change informing future food VC interventions. These changes should not be regarded as being independent but, rather, as complementary.

4.1. The transformative food value chain process

Food VC interventions provide entry points for development cooperation projects at the food supply system level (FAO, 2018). However, the traditional linear view of increasing production, jobs, and profits impedes integrated decision making (Horton et al., 2017) and blind out the complex and problematic feedback within modern food systems (Méndez, 2010; FAO, 2018; HLPE, 2019). A TFVC perspective suggests that VC interventions become instruments for reshaping food supply systems within planetary boundaries. This shift focusses to the selection process, intervention context, and monitoring process for food VC intervention outcomes.

Considering VC interventions as instruments for transformation towards sustainability means to further contextualize them as changeable components of food supply systems, with single sectors as elements. Accounting for good sector governance and the mapping of relevant food system links would then become an important first step towards making decisions on all kinds of VC interventions. Thinking through single-VC levels such as production, processing, distribution, preparation, and consumption as closely embedded in ecology, people, inputs, and institutions (Borman et al., 2022) means applying systemic thinking to what used to be rather linear models of VC development,

with the idea of synergistically combining interventions on multiple levels for supporting or initiating food system transformations towards "strong" sustainability.

Figure 3 describes the process of transformative VC development. It begins with any given or potential set of food VCs that are considered as core element of the food system and consisting of a set of actors performing food production, processing, trade, distribution, and consumption. Still, the correct VC development is driven by the productivity and growth paradigm, whereby value is essentially driven by.

The TVCD applies transformative capacity thinking in that it focuses on activating the creative capacities of local food system actors to assess these problems to rethink and rebuild their food system. This implies that stakeholders of the food system are included in the co-creation of the knowledge that informs food system analysis, finding solutions to food system sustainability problems, and the process of VC intervention design and selection (Folke et al., 2009, 2016). The TVCD perspective, therefore, suggests discussing the actionable consequences of applying transformative concepts like strong sustainability and resilience at the grassroots level, involving the perceptions of the actors, and contextualizing scientific knowledge in ways that enable the design of new food systems. In order to move from the conceptual to the actionable part in VC development intervention, practitioners and decisions makers need clear assessment instruments that allow to detect and to measure sustainability "problems" that my occur along food value chains (Bienge et al., 2009). Those sustainability assessment instruments are then used to design, implement and evaluate food value chain intervention programs.

Transformative capacity thinking has a direct impact on the role of stakeholders and the design of capacity-building activities in development cooperation: targeting actors' adaptation capacities for climate change risks, land fertility loss, decreasing water availability, or loss of relevant ecosystem services may no longer be a sufficient strategy accompanying food VC interventions as doing so may reduce the role of actors to shock absorption and adaptation when proactive engagement for and by the actors is needed to change the root causes of crises and vulnerability. The TVCD perspective targets transformative capacity building, that is, strengthening actors' ability to co-create and discuss "a *fundamentally new system when failures in ecological, economic, or social (including political) conditions reinforce each other and make the existing system untenable…*" (Walker et al., 2004, p. 4). This kind of capacity and system adaptation requires much more active roles at the grassroots, attention to new methods, and new types of capacity building that rely on problem solving and the co-creation of knowledge (Ziervogel et al., 2022).

From a potential set of existing food VCs selected for VC development (center of Figure 3), those that can be directly linked to previously identified hot spots of unsustainable food system outcomes are candidates for interventions alongside new food VC alternatives

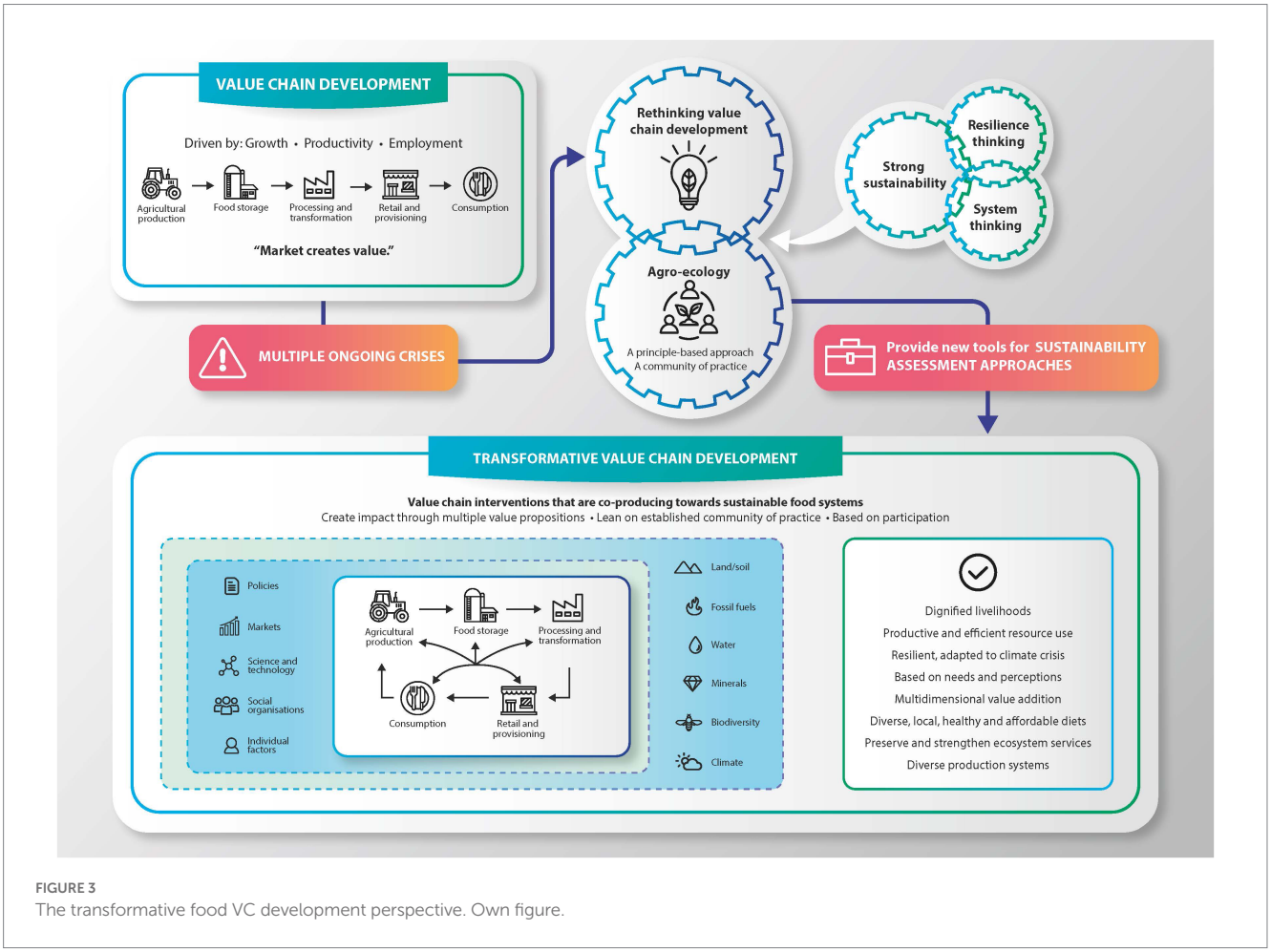

FIGURE 3
The transformative food VC development perspective. Own figure.

that are believed to do no harm or even regenerate the capacity of the food system to fulfill food system purposes.

4.2. A principle-based approach for making decisions along transformative pathways

Principles-based food system interventions and approaches for decision-making and evaluation are different from goals-driven projects and their evaluations (Patton, 2021). For example, principles-based project evaluation differs from traditional development project evaluation in that it can only evaluate the success or failure of processes of implementing principles, the outcomes directly associated with those principles, and the impact of innovative approaches to principles adaptation (Patton, 2021). Food system transformation is an open-ended continuous process of trial and error along which complexity and system dynamics pose limits to decision making following indicator-based monitoring and evaluation. Increasing VC stakeholders' chances of successfully embarking on transformative trajectories calls for an approach that informs initial decision making on food VC interventions and guides learning for actors who find themselves trapped in complicated trade-offs and feedback loops. In such a learning context, we caution against providing an extensive list of indicators (for the many reviews of assessment of sustainability dimensions, see, for example Lien et al., 2007; Janker et al., 2019; Franco Granovel et al., 2021; also Fraser et al., 2006; Reed et al., 2006; Coteur et al., 2018; Lairez et al., 2020; Belanche et al., 2021), but rather a limited set of clear and applicable principles derived from best practice and contextualized scientific facts (Schneemann and Vredeveld, 2015).

The implementation of a principles-based approach marks an important difference between traditional VC intervention concepts and interventions following the TVCD perspective. Deciding on a transformative VC intervention means introducing change at a certain entry point on a previously-agreed-upon set of principles. The application of simple principles is meant to ensure that a VC-level intervention does no harm and helps project stakeholders evaluate progress and create productivity and resilience.

A good example of a principle-based food system intervention that is heuristic in nature is the implementation of agroecological principles. Being in line with transformative capacity thinking, agroecology's practices demand the strong involvement of local actors in the co-creation of necessarily context-specific knowledge. Similarly, agroecological principles are based on strong sustainability assumptions and are based on knowledge about the preservation and integrity of ecological systems with full respect for planetary boundaries (FAO, 2018; HLPE, 2019). On the social dimension, co-creation and co-sharing of knowledge, a modified knowledge and information management system, and support to farmers as sustainable managers of natural resources offer the opportunity for social change that is induced and conducted by self-organized communities (Altieri, 2015). Involving farmers and their knowledge-generating role at the beginning of change processes means inviting their expertise in farming practices and decision making in the field and along the VC, as well as emphasizing the importance of intergenerational and gendered knowledge about land and resource use. The example of agroecology shows how 13 principles can underpin a theory for transformation of the food system and may guide intervention processes at different levels of the overall transformation starting at the farm and grassroots level and integrating all levels of society (FAO, 2018; Gliessman et al., 2019; HLPE, 2019). Applying agroecological principles to food VC interventions shows how food VC interventions may play important roles in all five levels of transformation. The agroecological principles provide guidance in the selection process for transformative VCs as well as for monitoring the implementation and impact of principles.

Strong sustainability, transformative capacity and system thinking coupled with a principles-based approach are important and interlinked elements in the trajectory of future food VC interventions, the Transformative Value Chain Approach *TVCA*. Agroecology as a set of principles backed by various sets of good practices may provide a set of guidelines relevant to the selection, design, and monitoring of future transformative VC interventions. The principles are derived from community of practice that has long been established despite the lack of clear definitions (Wezel et al., 2020). For the TVCA approach, agroecology offers a set of existing and agreed upon principles and elements, which draw pathway for transforming food systems. Concretely, the 13 principles and the 10 elements of agroecology have already been used to inform tools and methods for the appraisal and the evaluation of the sustainability of food value chains (Droppelmann et al., 2022; Enssle et al., 2022). This is particularly important as it informs decision makers and practitioners about the righteousness of the intervention, while keeping fundamental boundaries untouched. Those boundaries (or go's and no-go's) guiding the design and implementation of the future food value chain are derived from and inspired by the agroecological principles and elements can make sure that transformative value chains must promote social and ecological wellbeing in a way that:

- Promotes dignified livelihoods also including for marginalized and resource-poor groups.
- Promotes productive and efficient resource use.
- Are resilient, adapted to climate crisis.
- Based on needs and perceptions.
- Recognize multidimensional value addition.
- Promote diverse, local, healthy and affordable diets.
- Preserve and strengthen ecosystem services.
- Promote production system diversity.
- Embedded in a food system analysis.

In addition to embedding strong sustainability, transformative capacity at the same time, agroecology has the benefit of being a community of practice, whereby various actors from science, practice and political and social movements can co-learn, co-research, and co-produce towards sustainable food systems. Following this logic, the TFVC development perspective:

- is the result of contextualized analysis of sustainability problems in the relevant part of food systems and the analysis of the potential of VC interventions;
- is based on strong sustainability conceptualization that neither compromises nor trades off the social and environmental spheres;
- considers the particularities of potential markets for products produced in line with agroecological principles;

- supports socio-ecological innovations and practices for value addition along the VC that reflect an understanding of value that incorporates multidimensional values defined in a given context and not solely by end-consumers; and
- promotes instruments for activating the creative potential of all food VC actors to manage risks and increase their well-being based on cooperation and collective action; and pursues "real development collaboration" in interventions by fostering the co-creation of knowledge and active participation of stakeholders in the design, principles management, and assessment of project activities.

5. Conclusion

Food value chains are an integral part of a food system and remain central in the work of development agencies when it comes to food security, social justice and environmental sustainability (see, e.g., FAO, 2018; AGRA and UNDP, 2020; Barrett et al., 2020; IPES-Food, 2020). Despite their popularity among donors, the value chains interventions are nowadays at a crossroad. The multiple ongoing crisis have ultimately put a square emphasis on food as a nexus issue, urging to rethink the paradigms guiding the food value chains promotion.

We have argued that a change in paradigm may have consequences on three concepts: the food system thinking has its implications on the fact that the value chain interventions shall look beyond the linear concept of the "farm to fork" and integrate element of policy, society and the institutions surrounding the value chain. The strong sustainability concept is advocating for a beyond economic view in the value chain approach and for the necessity to trade-in sustainability goals instead of considering them as independent and conflictual. The new resilience thinking implies considering the actor's transformative capacity and their ability to shaping their own interpretation of sustainability.

Applying these conceptualizations to future value chain promotion deals with the challenging issue of how to go beyond relying on "cure-all" proposals for solving complex problems related to the transformation towards sustainability. Dealing with complex issues such as food systems transformation calls for a principle-based approach. Such an approach diverges from a how-to manual and rather takes a participatory and context-specific account of how future value chain promotion need to be designed and implemented, if they are to contribute to the transformation of food systems towards sustainability.

Finally, we explore existing transformative paradigms, such as agroecology, as it is an available and modular set of principles (and levels and elements) allowing to enough flexibility to deal with context specific issues while keeping the rigor of transformative imperatives and non-tradable sustainability outcomes.

The new perspective on VC interventions we proposed in this paper, labelled TVCD aims at building a bridge between the practice of food VC interventions and the findings of sustainability, resilience, and food system transformation research. TVCD interventions are based on a strong sustainability concept and are important entry points for development cooperation activities oriented towards the transformation of sustainable food systems. As drivers and showcases of change, they are the result of participatory problem solving through system thinking and may rely on the creation of multiple types of value that result from increased natural, social, or economic capital. TFVC interventions target both food system stakeholder capacities and process ownership as well as the natural and social capitals needed to produce, process, distribute, and consume food products.

In line with the findings of the High Level Panel of Experts on Food Security and Nutrition, we argue that for the transformation of the food system towards sustainability "a reconfiguration of knowledge systems is urgently needed, shifting towards a co-learning paradigm, bringing research and extension closer together and better linking international and national research and extension systems with local knowledge and farmer-to-farmer knowledge exchange" (HLPE, 2019, p. 116).

Data availability statement

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

Author contributions

AM has provided the concept, literature research, and redactional work. MH has provided input into the concept, has contributed with some written sections. HH has reviewed the paper and provided guidance for the general argument and the discussion. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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EDITED BY
Walter Odongo,
Gulu University, Uganda

REVIEWED BY
Marie Nakitende,
Uganda Martyrs University, Uganda
Joshua Wesana,
Mountains of the Moon University, Uganda

*CORRESPONDENCE
Foster Geoffrey Cossam
✉ cossamfoster98@gmail.com

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Determinants of postharvest losses along the baobab value chain in Malawi

Foster Geoffrey Cossam[1]*, Joseph Kuyamba Dzanja[1], Bonnet Kamwana[1], Dennis Etemesi Olumeh[2] and Dagmar Mithöfer[2]

[1]Department of Agribusiness Management, Faculty of Development Studies, Lilongwe University of Agriculture and Natural Resources, Lilongwe, Malawi, [2]Agrifood Chain Management Research Group, Humboldt-Universität zu Berlin, Berlin, Germany

Introduction: Wild fruits like Baobab are gaining status as a valuable food resource worldwide. As with other crops, the reduction of post-harvest losses is critical to enhancing sustainable utilisation of wild food resources. However, little information is documented on the magnitude and determinants of post-harvest losses (PHLs) amongst Non-Timber Forest Products (NTFPs), and baobab in particular.

Methods: This study used cross-sectional data collected from six districts to analyse PHLs along the baobab value chain in Malawi. A multistage sampling technique was used to sample 405 collectors, 96 traders, and 316 processors. Two-limit Tobit models were used to ascertain correlates of PHLs at each value chain level. The study quantified the value of PHLs and assessed the effect of socioeconomic factors on PHLs amongst baobab actors.

Results: We found that actors in the baobab value chain lose 7.78% of the total value of products held through PHLs. The results also showed that different sets of socioeconomic factors variably influenced PHLs amongst different value chain actors in the baobab value chain. For instance, gender was found to only correlate with PHLs amongst collectors. Whilst marital status was positively correlated with PHLs amongst collectors, and had a negative relationship amongst processors. PHLs at traders' level are influenced by the number of people employed by an actor, the ability of customers to specify product attributes, and a proportional reduction in sales volume due to COVID-19. The study recommends the provision of training in PHLs management, and the formulating and enforcing of Baobab product handling standards.

KEYWORDS

baobab (*Adansonia digitata* L.), post-harvest losses (PHL), Malawi, value chain, non-timber forest product (NTFP)

1. Introduction

Reducing postharvest losses (PHLs) is fundamental to enhancing sustainable utilisation of global food resources (Chadare, 2010). According to the World Bank (2011), managing PHLs is viewed as a viable alternative for increasing world food reserves. The world needs to increase food production by 60% by 2050, but efforts to increase food production are constrained by climate change, soil degradation, reduction of arable land, and dwindling fresh water reserves (Segrè et al., 2014). Management of PHLs is a better response to this need as it involves exerting limited pressure on existing production factors. According to Ayandiji et al. (2011), reducing

PHLs by 50% can increase food availability by 20% without increasing the area of cultivated land. As such, reduction of PHLs has a direct impact on household income and nutrition as it increases the amount of food that can be sold or consumed (Sheahan and Barrett, 2017). Despite efforts to reduce PHLs, they remain a major problem in many countries, especially in developing countries, where 15–50% of total food production is lost through PHLs (Affognon et al., 2015).

Research highlights that besides increasing food availability, reducing PHLs has other benefits including stabilising food prices, improving food safety, improving efficiency in resource allocation, and promoting value chain upgrading (Hodges et al., 2011; Shee et al., 2019; World Bank, 2020). Attempts have therefore been made to generate loss estimates of different food products, map hotspots of losses along value chains, standardise methodologies for estimating PHLs, evaluate the impact of innovations implemented to mitigate PHLs, and to suggest cost-effective alternatives to current PHL mitigation measures (Ayandiji et al., 2011; Sheahan and Barrett, 2017). However, there is still no consensus on the proper methodologies to follow when collecting, analysing, and reporting data on PHLs (Affognon et al., 2015; Sheahan and Barrett, 2017). Moreover, existing studies have concentrated on PHLs of staple food crops like maize, cassava, rice, and wheat, although researchers acknowledge that PHLs of other commodity Value chains need to be studied (World Bank, 2011; Affognon et al., 2015; Sheahan and Barrett, 2017). Hence, there is a dearth of knowledge on PHLs in other Value chains, which has resulted in food and economic losses and limited value chain upgrading (Chadare, 2010; Hodges, 2013).

One of the overlooked commodity value chains is the Baobab value chain. Baobab,[1] like other non-timber forest products (NTFPs), are regaining global popularity and acceptance as a super food due to their high nutrient and vitamin content. This global recognition is driven by changes in consumer preferences, whereby a majority of consumers now prefer natural food items. This preference has led to an increase in the volume of Baobab products traded on domestic and international markets (Amosi, 2018; Darr et al., 2020). In Africa, the expansion of domestic trade in Baobab products is also credited to the consumers awareness of its health benefits and the desire to support local products (Kruger and Mohamadi, 2021). Further, an increasing number of urban consumers in Africa appreciate the health and cultural benefits in wild food products like Baobab. Given the significance of Baobab in the food system and livelihoods (Buchmann et al., 2010; Sanchez, 2011), Baobab products lost through PHLs have substantial impact on the income and nutrition of actors throughout the whole baobab value chain. For example, in Southern Africa, a total of 238 t of baobab powder was sold in the local market, and 438 t were exported (Kruger and Mohamadi, 2021). In Malawi, the per capital revenue obtained from baobab enterprises in 2011, ranged between $2.5 to $715 (Munthali, 2012). Other studies such as (Jäckering et al., 2019) and (Welford et al., 2015) have also shown the relationship between baobab collection and improved incomes, in Kenya and Malawi, respectively.

Reducing PHLs has received policy prioritisation in Malawi. However, dealing with the PHLs of NTFPs like Baobab has been overlooked in these policies (Amosi, 2018). Policies such as the Malawi National Food Security Policy of 2006, the National Agricultural Policy of 2011, the National Forest Policy of 2016, and the Malawi Nation Export Strategy II (NES II) of 2022, which specifically affect PHLs management in Malawi, have rarely focused on NTFPs. The lack of visibility of PHLs of NTFPs in the national policies has been credited to the unavailability of clear and empirical information on the value, distribution, and determinants of the losses (North et al., 2014; Amosi, 2018). This information is crucial in order to identify solutions and guide priorities of action (Kikulwe et al., 2018). Unlike other fruits, Baobab has unique product attributes, handling methodologies, and climatic conditions under which crops grow (Kitinoja and Kader, 2015), hence the methodologies used to estimate PHLs in other fruit Value chains cannot work in the baobab value chain (Amosi, 2018). In addition, some interventions for mitigating PHLs implemented in other value chains, like the use of warehouse receipt systems, pesticides, and hermetic storage bags are not applicable in the Baobab value chain (Affognon et al., 2015; Sheahan and Barrett, 2017; Amosi, 2018).

Previous studies on PHLs have majorly focused on major crops such as pineapples (Tröger et al., 2020), tomatoes (Abera et al., 2020), maize (Abass et al., 2014), sweet potatoes (Shee et al., 2019), and fruits and vegetables (Porat et al., 2018). Further, recent reviews and metanalysis that study PHLs mainly consider studies on food grains, root crops, and vegetables and fruits (Affognon et al., 2015; Stathers et al., 2020; Debebe, 2022). To the best of our knowledge we only found one study Sanon et al. (2018) that has focused on descriptively analysing PHLs in NTFPs. Other studies (e.g., Adepoju and Salau, 2007; Meinhold and Darr, 2019), mention PHLs in NTFPs, but do not undertake any detailed analysis. In this paper, we seek to contribute to this gap in the literature by analysing the value of PHLs at various stages of the Baobab value chain and to assess the extent to which socioeconomic factors influence PHLs along the Baobab value chain in Malawi studies on socioeconomic factors influencing PHLs (Shee et al., 2019; Abera et al., 2020; Bendinelli et al., 2020; Debebe, 2022) do not look into losses in NTFPs, but rather focus on staples and cash crops. However, we also expect heterogenous patterns on the effect of socioeconomic factors relative to specific value chains. Even within the same value chain, PHLs may vary based on the geographical regions (FAO, 2011). Baobab is a unique case because it is a priority NTFP that is commercialized domestically and internationally.

The subsequent sections of this paper are structured as follows; section two provides the context of the baobab value chain; section three presents an overview of data and methods, describing the study area, data sources, sampling procedure, and data analysis. Section four presents and discusses the results and the last section concludes.

2. Baobab value chain in Malawi

In Malawi, most baobab trees grow naturally and are communally owned. However, individuals may claim ownership of baobab trees if they naturally grow on their private land. The communal ownership and non-uniform distribution of baobab trees pose challenges for the collectors to effectively manage baobab trees. Crucial pre-harvest practises that are common in other value chain like protecting trees

1 Baobab is multipurpose non timber forest product with products having numerous food uses and medicinal properties (Sidibe and Williams, 2002). The fruit pulp, the leaves and seeds are utilized as foods and also commercialized by rural populations in Africa (Chadare et al., 2009).

from diseases, preventing animal foraging, and ensuring harvesting of mature fruit are not followed in the baobab value chain (Amosi, 2018). Baobab fruits are mainly harvested between April and June, however some collectors would start in February and extend to October (Meinhold and Darr, 2022). The main actors in the baobab value chain include collectors, traders, processors, retailers, and consumers (Amosi, 2018; Jäckering et al., 2019). Collectors are responsible for harvesting and pre-processing of the baobab fruit. Fruits are mainly harvested by picking them from the ground or using long sticks with hooks to pluck them from the trees (Olumeh and Mithöfer, 2023). The main products that are sold by collectors are baobab fruit and pulp. Pulp is a cream-coloured powder that is embedded on the baobab seed, and it is extracted by opening the shell of the fruit using a machete or a hard object (Kaimba et al., 2020). Collectors either work individually or they are found in clubs. Collectors who are the members of baobab clubs or cooperatives may only collect fruits from designated forest and they follow strict guidelines to ensure that products are of high quality (Meinhold and Darr, 2022). The other category of the collectors does not belong to any grouping and they indiscriminately collect fruits. Actors at all baobab value chain levels store baobab products. However, there is no agreed proper storage material for baobab products especially for fruits and pulp. Some collectors store fruits in granaries and pulp in grain sacks that are coated with plastic, whilst others put the fruits in the yard, and part of livestock sheds. Collectors who store pulp in sacks with plastic lining argue that the plastic help to maintain the cream colour on pulp favoured by processing companies. Baobab traders mostly procure baobab from collectors. They market both whole fruit and pulp on seed. However, these traders are not specialised in baobab only, but baobab and its related products form part of the trader's portfolio (Meinhold and Darr, 2022). Majority of baobab purchases by traders were made between the month of April and June.

Baobab processing is mostly done informally, where processing is done in a microenterprise managed by an individual. Ice lollies were the most commonly processed baobab product. Other processed products include; juice, jam, baobab powder, coffee, and cosmetic products (Darr et al., 2020). More recently, formalised baobab processing has also emerged in Malawi (Meinhold and Darr, 2022). A baobab collector association is involved in manufacturing of baobab juice which is sold domestically. On average, 60 t of baobab pulp is processed annually into powder and then stored to be used as the main raw material for juice processing. Unlike other value chains in Malawi, trade in baobab products is only regulated for formal processors (Meinhold and Darr, 2022). The Malawi Bureau of Standards (MBS) are responsible for checking the processing facilities and the manufactured products, to ensure food safety and hygiene. Also, majority of the products processed by the formal enterprises are sold in supermarkets, hence, the MBS certification is a requirement.

FIGURE 1
A map showing the the target study sites in Malawi.

3. Data and methods

3.1. Description of study area

Data for this study was collected in six districts in Malawi, as indicated in Figure 1. Generally, Baobab fruits are collected in areas surrounding the southern part of Lake Malawi. Some Baobab collectors in the region are organised into clubs, cooperatives, and associations through which they collectively sell Baobab products. The Baobab collectors mainly sell Baobab products to traders from Malawi's cities (Amosi, 2018). The traders sell either to consumers or household processors in the cities. The Baobab processing companies in Malawi buy Baobab products directly from collectors through contractual agreements. For this study, data on Baobab collectors was collected in Salima, Dedza, Mangochi, and Neno districts. The districts were purposively selected because of their abundance of Baobab trees, and Baobab harvesting is one of the main income-generating activities. The climatic conditions in the study areas do not favour arable crop production due to the high temperature and erratic rainfall (Munthali, 2012). Data on traders and processors was collected

in Lilongwe and Blantyre. The districts were purposively selected for this study because of their active trade in Baobab products throughout the year (Munthali, 2012).

3.2. Data sources and instruments

Data was collected using a cross-sectional household survey approach. Semi-structured questionnaires were used to collect primary data at each value chain level. Face-to-face interviews were conducted at places chosen by respondents. These include homes, offices, market places, and the warehouses of Baobab cooperatives. Key informant interviews (KII) were also conducted to supplement data collected from personal interviews. Officials from Baobab processing companies and representatives of Baobab cooperatives were interviewed as key informants.

3.3. Sampling procedure

Given the variation of target respondents for this study, different sampling techniques were used for specific target groups. For collectors, we employed a multistage sampling procedure: First, we purposively selected the southern and the central regions in because of their dominance in Baobab collection in Malawi. Second, four districts with high proportions of Baobab collectors within the sampled regions were selected: Mangochi and Neno districts in the southern region and Salima and Dedza districts in the central region. Third, four villages were randomly selected from the sampled districts. Using a list of Baobab collectors – which was generated with the help of extension officers and Baobab project officers – we randomly sampled about 25 respondents in each village. Data was collected from a total of 405 collectors.

For traders and processors, we employed a two-stage sampling procedure that was complemented with a snowballing technique. In the first stage, three districts were purposively selected based on the density of traders and processors: Neno, Blantyre, and Lilongwe. In the second stage, a list of traders and processors was generated with the help of Baobab collectors and project officers. Finally, the snowballing technique was used to identify the target respondents. A total of 96 traders and 316 processors from villages and townships listed in Table 1 were interviewed.

TABLE 1 Sample of actors interviewed in each study area.

District name	Value chain level		
	Collectors	Traders	Processors
Mangochi	164	–	–
Dedza	74	–	–
Salima	36	–	–
Neno	131	23	–
Lilongwe	–	25	116
Blantyre	–	48	200
Total	**405**	**96**	**316**

3.4. Data analysis

3.4.1. Estimating the value of postharvest loss at each stage of the baobab value chain

Loss estimates at each stage along the baobab value chain were expressed as a percentage of the total value of Baobab fruits or Baobab products that were harvested, bought, or processed but not used for human consumption. The loss estimates were calculated for each main activity handled by the chain actor. Loss estimates were calculated following the procedure outlined by Egyir et al. (2008). However, the procedure was slightly modified by substituting "value" for "quantity" in the loss estimation equation. This enabled aggregation of loss estimates of different Baobab products handled by the same actor because products like ice-lollies, juice, and pulp cannot be aggregated on the basis of quantity. For each type of Baobab product handled, the following steps for estimating PHLs were taken:

The first step involved determining the value of Baobab products (j) lost (vq_j) by subtracting the quantity used for human consumption (tu_j) from the initial quantity held (tq_j) at each link in the value chain and multiplying the difference by the average market price (P_j).

$$vq_j = \left(tq_j - tu_j\right)P_j \tag{1}$$

The second step involved finding the mean value of Baobab (TVQ_{ij}) held and lost (VLQ_{ij}) for each Baobab product in the sample (n) at each ith link in the chain.

$$TVQ_{ij} = \left(\frac{\sum tq_j}{n}\right)P_i \tag{2}$$

$$VLQ_{ij} = \frac{\sum vq_j}{n} \tag{3}$$

However, Equation 2 was modified when determining the quantity of Baobab products held by collectors and processors. This was done to incorporate the possibility that Baobab products could change form whilst being handled by an actor. Two unique scenarios were thus observed. The first scenario was observed at the collectors' level, where actors harvested fruits but processed some of the harvested fruits into pulp. As such, they sold pulp and fruits. Consequently, the figure that denotes initial value held needed to reflect the added value gained from processing fruits into pulp. This was achieved following the procedure outlined below:

The value of fruits used for pulp production (V_{fp}) was determined by subtracting the value of fruits that were not processed into pulp (V_{fh}) and the value of fruits that were lost at the harvesting stage (VL_{fh}) from the value of the harvested fruits (V_{hf}).

$$V_{fp} = V_{hf} - V_{fh} - VL_{fh} \tag{4}$$

After that, the value added from processing fruits into pulp (VA_p) was determined by subtracting the value of pulp held (V_{ph}) from the value of fruits used to produce pulp (V_{fp}).

$$VA_p = V_{ph} - V_{fp} \quad (5)$$

The value of Baobab products held by collectors (VH_c) was determined by adding the value added due to processing fruits into pulp (VA_p) to the value of fruits harvested (V_{hf}). As can be seen, the processed pulp has value that can be broken into two parts: one which is equal to the value of fruits used to make pulp; and another which is equal to the added value from processing. Hence, it is reasonable to increase the value of harvested fruits by adding the value gained from processing activities only.

$$VH_c = V_{hf} + VA_p \quad (6)$$

The other scenario which necessitated modification of Equation 2 was observed at the processors level. At this level, processors were all using procured Baobab products (fruits and pulp) to produce different processed products. As such, the value of raw materials was captured in the value of the processed products. However, this value does not reflect the total value held by processors, since the processors incurred losses before they could produce the processed products. Hence, the value of Baobab products held by processors (VH_p) was determined by adding the value of processed products (V_{pp}) to the value of raw materials lost (VL_{rm}) before processing.

$$VH_p = V_{pp} + VL_{rm} \quad (7)$$

The third step involved calculating a loss ratio (VL) by taking a ratio of mean value lost to initial mean value held at each link in the chain.

$$VL = \frac{VLQ_{ij}}{TVQ_{ij}} \quad (8)$$

Lastly, the average of the sum of loss ratios for all links in the value chain was expressed in percentage form as follows.

$$\%TVL = \frac{\sum \frac{VLQ_{ij}}{TVQ_{ij}}}{N} \times 100 \quad (9)$$

Where:

%TVL = percentage postharvest loss per Baobabs products along the value chain.

VLQ_{ij} = mean value of Baobab products lost at each ith stage along the value chain.

TVQ_{ij} = mean initial total value of Baobab products held at each ith stage along the value chain.

N = total number of links along the chain.

3.4.2. Analysing correlates that influence postharvest losses

This study used a two-limit Tobit regression model – that is, a model censored on both sides – in order to analyse socioeconomic factors that influence PHLs of Baobab products at each level of the value chain in Malawi. The Tobit model was chosen as it is suitable for describing a relationship between a non-negative continuous variable that is cut off at a certain minimum value and a set of correlates (Gujarahti, 2009). The natural logarithm of value lost through PHLs was used as the dependent variable in the Tobit model. Data on the value of PHLs had minimum and maximum points where data values were concentrated. These points acted as censoring points for the Tobit model. The model was implicitly specified as:

$$y* = x\beta + \varepsilon \quad (10)$$

Due to presence of upper limit (ul) and lower limit (ll), the model was specified as:

$$y = \begin{cases} y^* if\ ul\langle y^*\rangle ll \\ 0\ if\ ll \le y^* \ge ul \end{cases} \quad (11)$$

The general model was explicitly specified, as shown in Equation 12. A parsimonious model for each value chain level was estimated. Consequently, some of the variables included in the general model were dropped.

$$\begin{aligned} lnPHL = a + \beta_1 Age + \beta_2 VPH + \beta_3 Edu + \beta_4 \exp + \beta_5 Storage \\ + \beta_6 PSDC + \beta_7 Labour + \partial_1 Training + \partial_2 Gender \\ + \partial_3 Region + \partial_4 CSPA + \partial_5 Married + \varepsilon_i \end{aligned} \quad (12)$$

We provide a description of variable measurements and hypothesised signs in Table 2.

TABLE 2 Description of variables.

Variables	Description	Expected sign
Male	1 = actor is male, 0 = actor is female	+
Age	Age of actor in years	–
Married	1 = actor is married, 0 = otherwise	–
Years of education	Years of formal schooling completed	–
Southern region	1 = actor lives in the southern region, 0 = otherwise	–
Years of experience	Number of years of experience	–
Log of quantity fruits harvested	Natural logarithm quantity fruits harvested	–
Storage day	Number of storage days	+
Labour	Number of labourers employed	–
Training in PHL	1 = actor received training in PHL reduction, 0 = otherwise	–
Customer specify product attributes	1 = customers specify attributes of Baobab products they want to be supplied, 0 = otherwise	+
Sales reduced COVID (%)	Percentage change in sales volume of Baobab products due to COVID-19	–

Variables that would influence the extent of PHLs amongst baobab actors are selected based on economic theory and empirical evidence on PHLs. The main variable of interest are derived from literature on determinants of PHLs (e.g., Abass et al., 2014; Shee et al., 2019; Abera et al., 2020; Tröger et al., 2020; Debebe, 2022).[2] Factors that commonly influence PHLs include household characteristics (gender, age, marital status, level of education, years of experience, access to training on PHLs) and shocks (reduction of sales due to Covid). For instance, we expect gender to have an influence on PHLs amongst baobab actors. In particular, we expect female baobab actors to exhibit less PHLs than male actors. Females are more likely to give care and management to their output than men, due to their expertise in NTFPs, they try to handle their products and reduce losses. Abera et al. (2020) made a similar observation in Ethiopia when they found that male farmers exhibited more maize losses than females. We expect older baobab actors to exhibit less PHLs than younger actors. This could be because, older actors, based on their experience, they are more likely to adopt and implement PHLs management technologies. Similar observation is made by (Tesfaye and Tirivayi, 2018) in Ethiopia. We hypothesise that educated actors are less likely to experience PHLs. Through education actors may be exposed to better product handling methods which may help to reduce post-harvest losses. A similar observation is made by Shee et al. (2019) in Uganda. We expect married actors to have less PHLs relative to their unmarried counterparts. Married actors are more likely to have access to more family labour, which offers support with better handling of products after collection (Abera et al., 2020). Number of days of storage of baobab are expected to positively influence PHLs amongst actors. During storage the produce may be lost due to storage pests or poor storage conditions. Storage pests were reported as one of the major factors that increased PHLs in Tanzania (Abass et al., 2014). Baobab actors who have access to labour are likely to experience less PHLs. Most post-harvest activities are labour intensive, hence having access to additional labour may support in undertaking the PHLs activities to reduce losses (Debebe, 2022). Shocks such as COVID-19 are expected to have a positive effect on PHLs. For instance, in Malawi, Covid was reported to have restricted movements of actors and limited transportation options (Matita and Chimombo, 2020).

4. Results and discussion

4.1. Socioeconomic characteristics of respondents

Table 3 presents a summary of socioeconomic characteristics of the actors involved in this study. The table shows that Baobab collection and processing is dominated by females. This observation is similar to other NTFP value chains, where they are viewed as a woman's domain (Sunderland et al., 2014). For instance, Olumeh and Mithöfer (2023) found that majority of baobab collectors in Malawi were female. Females may exhibit high participation in NTFPs value chains and baobab in particular because of limited barriers to entry, minimal use of inputs and technology, and low capital threshold (Mithöfer and Waibel, 2003; Kiptot and Franzel, 2011). At least 70% of actors at each baobab value chain level are married and more than 60% are from the southern region. The southern region of Malawi has been documented to have a higher intensity of baobab collection than other regions (Darr et al., 2020). More processors received training in PHL reduction than other value chain actors. The average number of years of experience in trading Baobab products for processors is 50% lower than other value chain actors. A plausible explanation for this observation could be that processing of baobab into various products has recently emerged due to the growing demand for natural products from wild fruits. (Meinhold and Darr, 2022). The average age for collectors is four-to-six years higher than for processors and traders. An average trader or processor has attended secondary school education. The number of members in a household of actors at each value chain level is about five members. An average trader or processor experienced a 40% decline in the sales volume of Baobab products due to COVID-19 in the 2020/2021 season. Majority of business activities in Malawi were disrupted due to the Covid restrictions on movements and gatherings. Close to 60% of business enterprises in Malawi reported a decline of business activities due to COVID (Matita and Chimombo, 2020). On average, traders store Baobab products for two months longer than collectors and one month longer than processors.

4.2. Extent of postharvest losses at each value chain level

Results in Table 4 show the proportion of PHLs incurred at each level of the Baobab value chain. Results shows that an average collector handles Baobab products worth MK 62,002 annually and loses an average of MK 1,167 of total value of Baobab products held, which represents a PHL of 1.88%. This loss is substantial in a country where an average person spends MK 598 per day (National Statistical Office (NSO), 2021). The table also shows that fruits are more susceptible to PHLs than pulp, as 3.94% of the total value of fruits held is lost, compared to 0.68% of the total value of pulp. The difference in the extent of PHLs for fruits and pulp can be credited to different upgrading strategies implemented by holders of these products. Most pulp producers are either from Dedza or Mangochi, where collectors have pursued horizontal upgrading in the form of collectors clubs. As a by-law, club members extract pulp together under the supervision of trained personnel, collectively called "the packaging department." The packaging department ensures that correct instruments and utensils are used to produce pulp of good quality. As a result, minimal PHLs are incurred. In addition, club members also pursue vertical upgrading in the form of supply contract with the Zankhalango Association. Under the terms of the contract, the Zankhalango Association provides training, equipment, and materials that help reduce PHLs. On the other hand, Baobab fruit collection and trading is largely unregulated. There is no supervision of fruit collection activities by trained personnel; neither do institutions like the Zankhalango Association provide materials to be used. As such, fruits incur more PHLs than pulp.

Results in Table 4 show that an average trader holds Baobab products worth MK 1,091,443 but incurs losses of MK 132,841, which represents annual PHLs of 12.17%. Traders incur more PHLs at grading, storage, and marketing stages. Traders claimed that a higher portion of Baobab product is lost at the grading stage because most collectors do not sell graded products. Losses for fruits are high at the marketing

2 Due to paucity in literature we rely on evidence from other value chains rather than NTFPs to discuss the selection of variables that may influence PHLs among baobab actors.

TABLE 3 Socioeconomic characteristics of respondents at each value chain level.

	Collectors (n = 405)	Standard deviation	Traders (n = 96)	Standard deviation	Processors (n = 316)	Standard deviation
Female (%)	56		38		92	
Married (%)	82		69		76	
Live in the southern region (%)	73		73		63	
Trained in PHL reduction (%)	43		48		63	
Customer specify attributes (%)	-		77		69	
Sales decline due to COVID (%)	-		48	21	41	19
Years of experience (mean)	9	5	8	6	4	3
Age (mean)	40	12	35	9	36	10
Years of education (mean)	5	2	9	2	10	3
Storage days (mean)	32	24	87	66	57	41
Labour (mean)	3	1	22	22	2	1
Household size (mean)	5	2	5	1	5	1

stage. Results from KIIs show that most PHLs at the marketing stage are in the form of rotten fruits. The rotten fruits are mostly discovered after cracking. For Baobab fruit traders, fruit cracking is only done at the marketing stage resulting in uncovering of higher PHLs at this stage. This study also found that most PHLs for Baobab products at Traders' level are incurred during storage, like in other food chains such as rice, tomato, and potatoes (Basavaraje et al., 2007;Anaba, 2018;Shee et al., 2019). This is because Baobab products are kept in storage for a long time, which exposes the products to various factors that exacerbate PHLs.

Table 4 also shows that an average processor, processes Baobab products worth MK 325,324 but loses MK 15,420 due to various PHLs, which represents a proportional loss of 4.74%. Processors lose substantial proportions of ice-lollies and coloured-pulp, losing 16.19 and 15.53% of total value held, respectively. Results from KIIs indicated that these high losses emanate from the processing methodologies that are used to make these products. Ice-lollies need to remain frozen once they are made. But due to frequent power cuts in Malawi, ice-lollies incur high PHLs because they are not kept in ideal conditions. Similarly, high PHLs are experienced when dried pulp is made wet when processors dye pulp with different colours to make coloured-pulp. Processors lack the proper equipment to facilitate drying (Amosi, 2018). As result, prolonged wetness leads to the development of microbes, which consequently promote PHLs.

4.3. Correlates of postharvest loss at each baobab value chain level

We assessed correlates of PHLs at the collectors, traders, and processor levels of the baobab value chain using two-limit Tobit models. The results of the estimated models are presented in Table 5. The results indicate heterogenous effects of socioeconomic factors on PHLs amongst actors in the baobab value chain, indicating that policy interventions for reducing PHLs in the Baobab value chain should be context specific.

Male Baobab collectors are less likely to incur PHLs (Table 5). This finding is different from the findings of Shee et al. (2019) and Kambewa et al. (2009), who reported that women incur less PHLs than men. Men and women may incur different PHLs because of differences in accessing training on PHL reduction. In this study, access to training in PHLs differed significantly by gender (Chi2(1) =4.75, p = 0.029). Men had an advantage over women in accessing PHL reduction training. Considering that women dominate Baobab collection, increasing women's access to PHL reduction training can help to reduce PHLs amongst collectors. Further, male collectors may be more likely to adopt strategies and technology meant for reduction of PHLs than female collectors. Gender has been found to be highly correlated with adoption of technology amongst smallholders (Owusu et al., 2017), with females exhibiting lower adoption rates.

Marital status was negatively correlated with PHLs amongst processors. A plausible explanation for these results could be due to access to additional household labour amongst married actors (Abera et al., 2020). Majority of PHL management activities during processing are labour intensive and access to family labour amongst married actors may help in ensuring adequate time of product handling which minimises losses.

Surprisingly, years of education was found to be positively associated with PHLs in Baobab products. More educated baobab collectors were more likely to incur PHLs. A possible explanation for this observation could be that educated Baobab actors are also actively engaged in other income generating activities, and therefore are likely not to spend more investments in management of baobab losses. Similar findings were also observed in Ethiopia where literate tomato farmers reported higher PHLs than illiterate farmers (Abera et al., 2020).

Collectors and processors who lived in the southern region of Malawi are more likely to incur PHLs than those who live in the central region. This observation may be attributed to differences in the harvesting season. Most Baobab fruits in the southern region (especially in Neno district) are harvested during the rainy season when there is insufficient sunlight to dry Baobab fruits. Weather changes are noted to exacerbate PHLs, especially when the harvested crop needs to dry, incidences of rainfall may hamper the drying process leading to losses (Abass et al., 2014).

The quantity of Baobab fruits harvested was positively correlated with the PHLs incurred by collectors. These results indicate that collectors who hold more fruits are more likely to incur PHLs. A probable explanation for our results could be that collectors who have large quantities are more likely to have pressure in undertaking good

TABLE 4 Extent of postharvest losses at each value chain level.

	Collectors			Traders			Processors					
Loss stage	Fruits (*n* = 405)	Pulp (*n* = 309)	Overall (405)	Fruits (*n* = 55)	Pulp (*n* = 62)	Overall (96)	Fruits (*n* = 2)	Pulp (*n* = 316)	Juice (*n* = 307)	Ice-lollies (*n* = 30)	Coloured-pulp (*n* = 21)	Overall (316)
Harvesting	0.01%	–	–	–	–	–	–	–	–	–	–	–
Assembling	0.03%	–	–	1.56%	1.16%	–	–	–	–	–	–	–
Grading and sorting	0.03%	–	–	4.50%	1.05%	–	–	–	–	–	–	–
Temporal processing (drying, etc)	0.10%	–	–	1.79%	1.26%	–	–	–	–	–	–	–
Loss during storage	3.04%	0.66%	-	4.53%	4.62%	-	4.65%	4.84%	–	–	–	–
Loss during processing	–	–	–	–	–	–	–	–	1.72%	8.84%	10.96%	–
Loss during marketing	0.36%	0.02%	–	3.64%	2.24%				1.37%	7.35%	4.57%	–
Percentage of total value lost	3.94%	0.68%	1.88%	16.02%	10.34%	12.17%	4.65%	4.84%	3.08%	16.19%	15.53%	4.74%
Mean annual value held (MK)	39,088	51,537	62,002	545,089	1,290,600	1,091,443	68,500	104,358	325,772	19,783	26,972	325,324
Mean value lost (MK)	1,598	267	1,167	87,327	120,303	132,841	3,185	5,051	10,182	3,314	3,825	15,420
Mean quantity lost	453Kg (216Kg)	370Kg (197Kg)		326Kg (235Kg)	272Kg (244)		15Kg (21Kg)	17Kg (17Kg)	40 L (33 L)	10 L (11 L)	7Kg (10)	

standard deviations are in parenthesis.

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TABLE 5 Correlates of postharvest losses amongst Baobab collectors, traders, and processors.

Variables	Collectors		Traders		Processors	
	Coef	Std. error	Coef	Std. error	Coef	Std. error
Male	−0.79**	(0.37)			−0.20	(0.20)
Age	0.00	(0.01)			0.00	(0.01)
Married	0.56	(0.37)			−0.29**	(0.13)
Years of education	0.06*	(0.03)	0.04	(0.04)	−0.01	(0.02)
Southern region	1.23***	(0.23)			0.45***	(0.11)
Years of experience	−0.02	(0.02)			0.01	(0.02)
Log of quantity fruits harvested	0.31***	(0.10)				
Storage day	0.01**	(0.00)	0.00***	(0.00)	0.00***	(0.00)
Labour			0.02***	(0.01)	0.06*	(0.03)
Training in PHL			0.47**	(0.23)	−0.49***	(0.12)
Customer specific attributes			0.84***	(0.27)	−0.11	(0.12)
Sales reduced COVID (%)			0.01***	(0.01)		
Constant	0.96	(1.12)	8.33***	(0.61)	9.40***	(0.35)
var(e.lnPHLprocessors)	2.97***	(0.31)	1.10***	(0.17)	0.82***	(0.09)
Log likelihood	−298.71		−138.96		−379.99	
Pseudo R2	0.06		0.12		0.08	
Observations	403		95		315	

Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

handling practises and finding adequate storage facilities, which may lead to PHLs. In Uganda, pineapple value chain actors reported economic losses as a result of poor handling practises (bruised, squeezed, injured) that led to the loss of quality (Tröger et al., 2020).

The positive coefficient of storage indicates that Baobab products are more likely to incur PHLs when they spend more days in storage. The results are coherent with the findings of Kitnoja et al. (2015), who found that, an extended storage period creates a conducive environment for loss agents to cause damage. Results from the KIIs showed that Baobab products like juice are made without adding preservatives. As such, the products become prone to microbial attacks when storage time increases resulting in increased likelihood to incur PHLs.

Access to training in PHLs was found to have mixed effects amongst Baobab traders and processors. Whilst Baobab traders who had access to PHLs training were less likely to experience PHLs, processors with access to similar training were more likely to incur PHLs. A probable explanation for this observation could be based on the quality of training received by the traders and processors. It may be that they are only trained in managing PHLs in the raw products (Baobab whole fruit and pulp), which are mostly traded by traders, as opposed to the Baobab-processed products that are mostly handled by processors. The results on traders are similar to the results of Shee et al. (2019) whilst studying PHLs along the maize value chain in Uganda.

The reduction of sales due to Covid-19 was positively correlated with PHLs amongst traders. Reduction of sales volume may lead to an increased likelihood of PHLs when Baobab products are improperly stored for a long time. The control and management measures to Covid-19 put in place a lot of movement restrictions that had an effect to both demand and supply markets, thus compelling traders to store baobab products for longer durations. Our results corroborate with the findings of Underhill et al. (2023) who found that approximately 70% of market vendors of fruits and vegetables in Tonga, Fiji, and Samoa reported that on farm crop losses had increased due to COVID-19.

5. Conclusion and recommendations

Wild fruits are gaining status as a valuable food resource worldwide. As with other crops, the reduction of postharvest losses is critical to enhancing sustainable utilisation of wild food resource and strengthening value chains for local development. Baobab, like other wild fruits are regaining global popularity and acceptance as a super food due to their high nutrient and vitamin content. However, little information is documented on the magnitude and correlates of postharvest losses (PHLs) along the Baobab value chain in Malawi. Using a cross sectional data set from baobab collectors, traders, and processors in Malawi we employ the loss estimation procedure outlined by Egyir et al. (2008) and tobit models to assess the magnitude of PHLs and the effect of socioeconomic characteristics on PHLs, respectively.

The results show that 7.78% of the total value of Baobab products held by actors along the Baobab value chain in Malawi is lost through different forms of PHLs. A large proportion of the losses are incurred at storage and marketing stages. The results also indicate that PHLs at different value chain levels are influenced by different sets of socioeconomic factors. Collectors who are male, more educated, and more experienced are less likely to incur PHLs. The likelihood of incurring PHLs at the traders' level increases with a greater COVID-related sales reduction, if customers specify product attributes, and if more labourers are recruited. Processors are less likely to incur PHLs if the processor is female, married, and has received training in PHL reduction.

Our findings have key policy implications, for instance we recommend that development practitioners and relevant government institutions should provide training in the proper handling of Baobab products to all actors along the Baobab value chain to reduce PHLs. The training content should emphasise the better management of Baobab products at storage and marketing stages. In addition, the government, through the Malawi Bureau of Standards (MBS), should implement and enforce product-handling standards to ensure the production of quality products that are capable of withstanding PHLs. National policy strategies need to guarantee inclusion of sustainable NTFPs storage infrastructure. This will have a positive effect on reducing losses during storage of baobab products.

Because of complexity in estimating value lost due to quality deterioration, we could not include it in our assessment of PHLs. Failure to include PHLs attributable to quality loss means that our estimate for PHLs is only composed on the losses that are quantifiable. Also, data on quantity lost is based on self-recall data and could be affected by strategic bias of the respondent. Rather than using actors' self-reported estimates, future research should use direct measurement methods and include qualitative PHLs.

Data availability statement

The datasets presented in this article are not readily available because the data used for this manuscript is still being used in development of other research articles. Requests to access the datasets should be directed to FC; cossamfoster98@gmail.com.

Author contributions

FC, JD, BK, and DM contributed to the conception and design of the study. FC and DO organised for data collection and performed statistical analyses. FC wrote the first draft of the manuscript. DO and DM wrote sections of the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2023.1119107/full#supplementary-material

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EDITED BY
Walter Odongo,
Gulu University, Uganda

REVIEWED BY
Bettina König,
University of Kassel, Germany
Funso Raphael Kutu,
University of Mpumalanga, South Africa

*CORRESPONDENCE
Niloofar Khalili
✉ Niloofar.Khalili@zalf.de

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Adoption of processing technologies and innovative food preservation techniques: findings from smallholders in the Lindi Region in Tanzania

Malika Sarr[1], Zahra Majili[2], Niloofar Khalili[1]*, Custodio E. Matavel[1], Hadijah A. Mbwana[2], Jacob Kaingo[2], Katharina Löhr[1,3] and Constance Rybak[1,3]

[1]Leibniz Centre for Agricultural Landscape Research (ZALF), Program Area 2 "Land Use and Governance", Working Group "Sustainable Land Use in Developing Countries", Müncheberg, Germany, [2]Department of Human Nutrition and Consumer Sciences, Sokoine University of Agriculture, Morogoro, Tanzania, [3]Humboldt-Universität zu Berlin, Thaer-Institute, Division Urban Plant Ecophysiology, Berlin, Germany

Adopting processing technologies and innovative food preservation is crucial for improving the food security and nutritional status of rural populations in Tanzania and other countries in the Global South. However, low adoption rates among smallholders highlight the need for a better understanding of farmers' decision-making processes. The aim of this study is to examine extrinsic and intrinsic factors influencing smallholders' decision-making processes in the adoption of innovative food processing and preservation techniques (specifically, pigeon pea flour-based products, threshers, dehullers) in Mitumbati and Mibure in the Lindi Region in Tanzania. Primary data on 555 farm households were collected using a standardized survey. Extrinsic influential factors were analyzed using binary logistic regression analysis. The results on internal decision-making are based on an analysis of barriers and motivations identified by farmers in relation to the uptake of the different innovations. Training and awareness emerged as the most significant factors positively associated with the adoption of all innovative processing and preservation techniques. Moreover, the results show that the primary drivers for smallholders in the study region to adopt innovative technologies were the potential health benefits and time savings they offered. The main challenge they faced was a lack of knowledge about the innovations. The results indicate that disseminating knowledge is crucial for the successful adoption of innovative processing technology in the study region. Improving and expanding training programs to be more inclusive can help to create incentives and overcome barriers, leading to increased adoption.

KEYWORDS

adoption, smallholder farmers, Tanzania, processing technology, pigeon peas

1 Introduction

The adoption of new processes and technology can play a crucial role in supporting sustainable agriculture and promoting economic growth in African countries. By increasing yields and productivity, improving access to markets, and improving better risk management, the adoption of new technologies can bring many benefits to smallholder farmers and contribute to food security in the region. Agricultural productivity and related food and nutrition security are limited by poor harvest and processing practices, limited storage and food preservation techniques, as well as a lack of dietary knowledge (Okoedo-Okojie and Onemolease, 2009; Affognon et al., 2015; Adeyeye, 2017; Ambuko, 2017).

There are various factors influencing the adoption of agricultural innovations, which can be categorized into extrinsic and intrinsic factors. Extrinsic factors include personal, physical, institutional, and socio-economic characteristics of adopters and their environment (Feder et al., 1985; Sheikh et al., 2003). Farmers' knowledge, perception and attitudes towards an agricultural innovation can be classified as intrinsic factors (Adesina, 1995; Meijer et al., 2015; Jha, 2021). The extent to which the different factors impact adoption is highly context-dependent, including, among others, on the type of innovation, on the cultural context, and on the geographic conditions (Feder and Umali, 1993; Ruzzante et al., 2021). Studies tend to focus on the influence of extrinsic factors, whereas the impacts of intrinsic factors are still understudied (Adesina, 1993, 1995; Meijer et al., 2015; Bisheko and Rejikumar, 2023). Existing literature on agricultural innovation adoption primarily examines practices and cultivation methods aiming to increase agricultural production (Awotide et al., 2012; Mottaleb, 2018; Zegeye et al., 2022). There is comparatively little existing research on the adoption variables of agricultural practices at the post-harvest level (Okoedo-Okojie and Onemolease, 2009; Arslan, 2020). The study of Bisheko and Rejikumar (2023) highlights a notable scarcity of research dedicated to the adoption of processing technology among smallholder farmers in sub-Saharan Africa and South Asia.

In Sub-Saharan Africa (SSA), post-harvest losses are estimated to range between 30 and 50%, exceeding the global average (Deloitte South Africa, 2017). The impact on small-scale farmers is particularly harsh, as their livelihoods are heavily dependent on food production (Sheahan and Barrett, 2017). While food losses can occur throughout the entire value chain, in smallholder farming systems these primarily originate from poor harvest and processing practices, alongside limited storage and food preservation techniques (Adeyeye, 2017; Ambuko, 2017). Enhancement of existing techniques through innovative processing and preservation methods bears the great potential of not just preserving agricultural goods and their nutritional quality but also further ensuring year around availability (Adeyeye, 2017). Further, farmers' livelihoods and income levels can be significantly impacted through the uptake of post-harvest value addition technologies (Agor et al., 2020). However, despite these potentials, the actual adoption of innovative practices by smallholders is relatively slow (Meijer et al., 2015; Dhehibi et al., 2019). Understanding farmers' decision-making processes alongside the determinants and barriers of agricultural innovation adoption can pave the way to more successful implementation (Dhehibi et al., 2019; Arslan, 2020).

Pigeon peas *(Cajanus cajan L.)* (PP) are legumes that are widely cultivated in semi-arid regions (Sharma et al., 2011; Sarkar et al., 2018). They are rich in fiber, vitamins (niacin and riboflavin), minerals (phosphorus, iron, and magnesium), and essential amino acids (lysine, methionine, and tryptophan) (Saxena et al., 2002; Karri and Nalluri, 2017). Due to their nutritional properties, they can contribute significantly to food and nutrition security. Tanzania (5.16 kg/year) holds the third highest *per capita* consumption rate of pigeon peas in SSA after Malawi (22.35 kg/year), and Kenya (6.72 kg/year) (Indexbox, 2018). In the agricultural season 2019 to 2020, the total harvested area of pigeon peas in Tanzania was 97,092 ha. After the Mtwara region, and the Manyara region, the Lindi region has the third largest production area for pigeon peas (16,540 ha, 17.2%) (URT, 2021). The Lindi region is a high production area accounting for almost half of the national pigeon pea production in Tanzania (Mponda et al., 2014). They are primarily cultivated for domestic consumption and as a source of revenue (Mergeai et al., 2001; Shiferaw et al., 2007). However, in Tanzania legumes, including pigeon peas, are still not widely consumed (Mfikwa and Kilima, 2014; Majili et al., 2020, 2022). Consumption is particularly low during the lean season due to high post-harvest losses and a lack of diversified and shelf-stable pigeon pea products (Majili et al., 2020, 2022). Due to the high nutritional value and the wide cultivation in the Lindi region, pigeon peas were selected as a core crop for processing technologies and products in the Vegi-Leg project, which seeks to improve the food and nutrition security situation of pigeon pea farmers in the Lindi region. This study is embedded in the final phase of the Vegi-Leg project after the identification, development, and implementation of pigeon pea processing technologies and products using co-design to assess the adoption of improved technologies and processing for reducing post-harvest loss and improving the nutritional value, thus enhancing food and nutrition security.

Pigeon pea farmers in the study region rely heavily on traditional processing and preservation methods, leading to time-consuming practices and significant post-harvest losses. To address this, threshers and dehullers were selected, developed, and implemented in a participatory approach, aiming to provide innovative techniques to meet the needs for improved processing options of target groups. Additionally, the introduction of pigeon pea flour-based products aimed to diversify diets and offer shelf-stable, nutritious options during the lean season. Threshers were petrol-driven and able to process up to 800 kgs of produce per hour, while dehullers were electric and could treat a maximal quantity of 300 kgs per hour. As part of the project, farmers were trained in machinery usage, with selected individuals forming "processing groups" in order to train others (train-the-trainer concept). Maintenance and coordination of machinery were assigned to specific individuals or groups in each village. A fee was charged based on grain weight to cover fuel expenses. The project's selection process of pigeon pea flour-based products involved a participatory approach, incorporating input from the local population (Majili et al., 2022). The production process involves pre-treatment, milling, and sieving to obtain pigeon pea flour, which can then act as a substitute for, or added to, wheat flour. Farmers were familiarized with simple recipes to create a range of food items based on PP flour. Training sessions were conducted to facilitate the adoption and dissemination of the production process among farmers. Underlying this study's main objective, there are two research questions. (i) What is the adoption rate of newly introduced post-harvest technologies and pigeon pea flour-based products by farmers in the Lindi region (Tanzania) and (ii) How do extrinsic and intrinsic

factors impact farmers' adoption? The study was conducted in the frame of a research project focusing on the development of processing technologies to improve the nutrient quality of products and the perennial availability of pigeon peas. Using co-design, two different pigeon pea processing technologies, namely pigeon pea threshers, and dehullers, alongside innovative pigeon pea flour-based products (instant porridge, noodles, Maandazi, Bhajia, Chapati, bread, and biscuits) were selected, developed, and implemented in the project setting.

By assessing the adoption rate and drivers for adoption, the study results contribute to the improvement of implementation processes of innovative processing technologies and products to sustainably transform elements of the pigeon pea value chain, addressing food and nutrition insecurity on the ground.

2 Methods

2.1 Research framework

The empirical literature on agricultural technology uptake in the Global South identifies a variety of extrinsic factors impacting adoption, including the socio-economic characteristics of adopters (e.g., age, gender, education) (Doss, 2001b; Abdulai and Huffman, 2014; Jha, 2021), farm specific determinants (land size, labor availability) (Feder et al., 1985; Okoedo-Okojie and Onemolease, 2009; Raghu et al., 2014), and extension effects (e.g., training, familiarity) (Yaron et al., 1992; Imaita, 2013; Pignatti et al., 2015). There is relatively little research that emphasizes the significance of farmers' internal attitudes and perceptions when it comes to adopting technology (Adesina, 1995; Meijer et al., 2015; Jha, 2021), but some find an impact of these factors in multiple settings (Kulshreshtha and Brown, 1993; Ammann et al., 2022). Additionally, a multitude of concepts strive to explain the interrelations of these variables within farmer decision making regarding the uptake of innovations [e.g., Rogers (2003), Fishbein and Ajzen (1975), Meijer et al. (2015)]. Rogers (2003) finds five distinct elements that impact the rate at which an idea is adopted: relative advantage, compatibility, complexity, trialability, and observability. The theory of reasoned action (TRA), by Fishbein and Ajzen (1975), highlights the importance of an individual's attitude and subjective norms toward a behavior as being significant factors for decision-making. Yet, the importance of their influence depends on the agricultural innovation in consideration, geographical location, and other context specific aspects (Feder and Umali, 1993; Ruzzante et al., 2021).

In this study, to investigate the drivers for agricultural technology adoption, it is important to not only consider extrinsic factors, such as the farmers' socioeconomic characteristics and farm environment but also intrinsic factors based on their perceptions of pigeon pea innovative produce and processing technology. Further additional factors for communication and extension should be incorporated. Therefore, to assess adoption behavior and those underlying drivers impacting its degree, a simplified version of the analytical framework proposed by Meijer et al. (2015) is applied. This framework fits well as it understands farmers' decision-making as a complex nonlinear process and distinguishes between extrinsic and intrinsic influential factors. The intrinsic factors, namely farmers' knowledge, perceptions, and attitudes, build the basis, directly influencing farmers' adoption decisions, which are influenced by a range of extrinsic factors, such as farmers' characteristics, environmental characteristics, as well as intervening factors communication, and extension. Thus, the chosen framework helps to analyze the complex adoption process in a systematic approach while structuring different impact factors. Meijer et al. (2015) include another group of influential extrinsic factors, referring to the characteristics of the agricultural technology, more precisely its costs and benefits. For the purpose of this study, the framework was simplified, omitting these characteristics due to the co-design approach of this research. The development of innovations was carried out in a participatory approach with all relevant stakeholders. As potential adopters were included in this process, costs and benefits were considered to be aligned with their needs.

2.2 Study area

This study was conducted in two villages of the Ruangwa (Mibure) and the Nachingwea (Mitumbati) districts of the Lindi Region in Tanzania (Figure 1). Target households are mainly engaged in subsistence farming or small-scale farming to create income and provide food for household consumption. The prevalence of malnutrition in the Lindi region is particularly severe with the prevalence of high stunting in children under the age of five (54%) (URT, 2016; Indili et al., 2018). The region is semi-arid and districts were purposefully selected due to market accessibility and for being the main pigeon pea producers in the region. The villages were chosen based on their high production volume of pigeon peas, which are cultivated during the rainy season (December–March) and intercropped with maize [compare Majili et al. (2020, 2022)].

2.3 Data collection and sample

This study was embedded in the final phase of the Vegi-Leg project, which emphasized to select, develop and implement nutrition-sensitive post-harvest pigeon pea technologies and products for improved nutrition security using co-design. Within the entire project framing, a baseline and endpoint survey were conducted using a random sampling procedure to analyse the impact of innovations. Co-design was applied for the problem definition, selection, development, and implementation of post-harvest interventions by all relevant stakeholders such as pigeon pea farmers, local policymakers, extension services, and academia. To address the fostering and hindering factors for adoption, this study was enclosed in the endpoint survey of the Vegi-Leg project (random selection procedure).

The study population comprises female and male pigeon pea farmers ($n = 555$) who were randomly selected. Survey participants were part of a research project aiming at the development of processing technologies and preservation techniques to improve the nutrient quality of products and the perennial availability of pigeon peas. The key inclusion criterion for participation in the project is that the farmer had grown pigeon peas in the last 3 years prior to the project's start. As part of the endline survey of the project in August 2021, a quantitative household survey was used to collect information on farmers' adoption behavior and related extrinsic and intrinsic influential factors. The survey consisted of several sets of structured

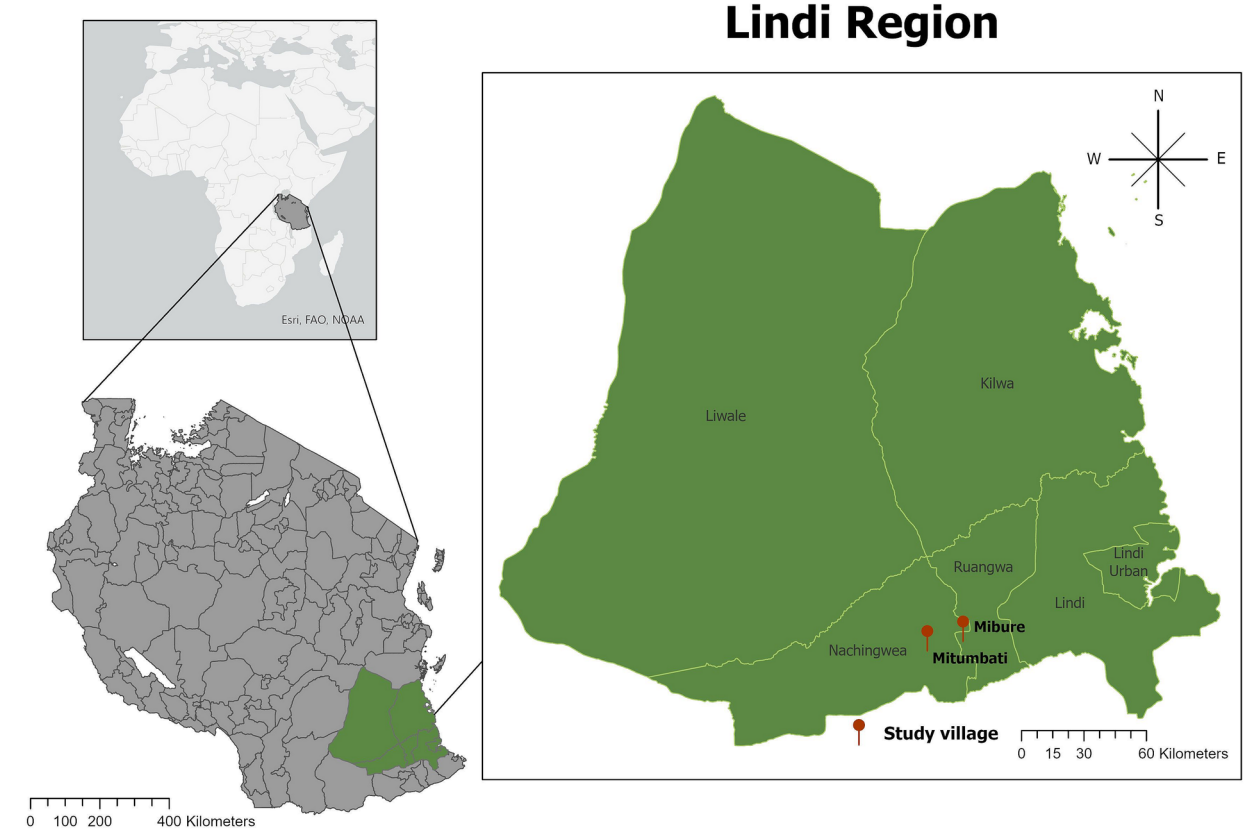

FIGURE 1
Geographic location of the study region Lindi Region in southeast Tanzania (green) and study villages (red) (Resource: Geo dataset: Humanitarian Data Exchange (2022)).

questionnaires, with data collected by 15 project enumerators. Interviews were approximately 90 min long and carried out in Swahili.

One part of the survey focused on the collection of extrinsic factors, such as information on household demographics, PP production, processing, consumption, extension, and experience with technologies. The variables examined within this study are listed in Table 1 below and were chosen based on extensive literature research, as they are already linked to adoption in a variety of studies [e.g., Feder et al. (1985), Okoedo-Okojie and Onemolease (2009), Raghu et al. (2014)]. Adoption was determined as a binary categorical variable referring to whether the farmer is using an innovative practice or not. Apart from the questionnaire on socio-economic information, intrinsic factors are assessed as farmers' perceptions and attitudes toward adoption. Survey participants received an additional questionnaire asking for 1) drivers and 2) barriers related to the use of processing and preservation innovations. This section included predefined response options that are aligned with the conceptual and theoretical background of this study (Leite et al., 2014; Meijer et al., 2015; Antwi-Agyei et al., 2021). The entire survey was carried out according to the guidelines laid down in the 'Declaration of Helsinki' and approved by the National Institute for Medical Research, Dar es Salaam, and the Ministry of Health, Community Development, Gender, Elderly and Children in Dodoma, Tanzania (NIMR/HQ/R.8a/Vol.IX/3040). Written informed consent was obtained from all farmers.

2.3.1 Descriptive statistics

Descriptive statistics are used to describe the characteristics of the households and analyze the adoption rates. Continuous variables, like age, household size, and farm size, are analyzed using averages and standard deviations, whereas, for categorical variables (education, literacy, gender, off-farm income, and awareness of technology), frequencies and percentages are calculated. Likewise, to identify the key intrinsic factors driving technology adoption, the information from farmers' interviews on motivation and barriers to innovation uptake was analyzed using frequency analysis.

2.3.2 Binary logistic regression

A logistic regression model was constructed for each innovation (threshers, dehullers, and PP flour-based products) to determine those key factors that influence farmer adoption in the region. The use of qualitative response models is necessary to model the connection between a farmer's decision to adopt or not adopt innovative technology and the independent variables (Ntshangase et al., 2018). In this research, a logit model is used. Logit models are widely applied in adoption technology studies because they are well-suited for analyzing binary outcomes and due to their simplicity in application (Sheikh et al., 2003; Mlenga and Maseko, 2015; Ntshangase et al., 2018). The model allows researchers to estimate the probability of adoption from a set of independent variables, such as demographics, socioeconomic status, and attitudes toward the innovation. Logit models are also able to account for non-linear relationships between

TABLE 1 Description of explanatory variables.

Variable	Description and Measurement Type	Variable type	Expected outcome (+/–)
Village	Name of the village (0 = Mitumbati, 1 = Mibure)	Categorical	+–
Age	Age of the head of the household (in years)	Continuous	+–
Gender	Gender of the head of the household (0 = male; 1 = female)	Categorical	–
Household size	People living in the household (including visitors staying more than 3 months)	Continuous	+
Education	Highest level of education of the survey respondent (0 = no formal; 1 = some primary school; 2 = primary school; 3 = secondary school)	Categorical	+
Literacy	Literacy assessment of the respondent by the interviewer (0 = read and write: 1 = not able read, 2 = write to some extent)	Categorical	+
Farm size	Approximation value calculated by the statement on the cultivated area of the respondent (in hectares)	Continuous	+–
Off-farm income	Additional income sources other than farming, (1 = yes, 0 = otherwise no)	Categorical	+–
Technology skills	The household has prior experience in the use of technology (1 = yes, 0 = otherwise no)	Categorical	+
Awareness of technology	Household is familiar with the specific innovation (0 = no; 1 = yes)	Categorical	+
Training	Household received training (1 = yes, 0 = otherwise no)	Categorical	+

these factors and adoption, making them a useful tool for identifying the key drivers of technology adoption in different contexts.

From the input explanatory variables, the binary logistic regression model builds a logistic probability function for the dependent variable of innovation adoption. In line with Baltagi (2021), Gujarati and Porter (2009), and Laduber et al. (2016), the general logistic distribution equation for the adoption of agricultural technologies is expressed as follows in Equation 1:

$$Logit(\gamma) = \ln\left(\frac{P}{1-P}\right) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n + \varepsilon i \quad (1)$$

Where, γ = is the dichotomous dependent variable that refers to whether the farmer is using a technology/product (innovation adoption = 1, and 0 = otherwise); P = Probability of adopting; $1\text{-}P$ = Probability farmer of not adopting; α = Constant term (intercept); $\beta_1 \ldots \beta_n$ = coefficients of the explanatory variables; $X_1 \ldots X_n$ = explanatory variables; and εi = error term of the model.

In this study, the extrinsic explanatory variables of importance are those that are assumed to influence the adoption of the respective innovative processing practices. Table 1 presents the explanatory variables and factors hypothesized to impact adoption.

The logistic regression model for the *Adoption* of the different innovative technologies is specified in Equation 2 as:

$$\begin{aligned} Logit(Adoption) = {} & \beta_1 village + \beta_2 age + \beta_3 gender + \beta_4 hhsize \\ & + \beta_5 education + \beta_6 literacy + \beta_7 farmsize \\ & + \beta_8 offar\,\min come + \beta_9 techskills \\ & + \beta_{10} training + \beta_{11} awareness \end{aligned} \quad (2)$$

Within the scope of this study, three regression models were designed to calculate farmers' likelihood of *Adoption* for each innovation. The explanatory variables were tested to ensure compliance with technical requirements for the data, set such as a lack of significantly influential outliers, the linearity of the logit for continuous variables, the absence of multicollinearity, and the independence of errors (Stoltzfus, 2011; Laduber et al., 2016; Fernandes et al., 2020). In line with Baltagi (2021), Laduber et al. (2016), and Okoedo-Okojie and Onemolease (2009), the models were assessed for their goodness of fit using the Omnibus test (likelihood-ratio χ^2 test), the overall model correct prediction, and the Hosmer-Lemeshow test. The statistical software package SPSS version 27.0 was used for the econometric analysis.

3 Results

3.1 Socioeconomic characteristics of the respondents

Information on the socioeconomic characteristics of the respondents is listed in Table 2. The age of the household head ranged from 21 to 99 years, with an average of 51 years (±17.88 years SD). At 79.5%, most households are headed by men; the remaining fifth are led by women. The average respondent's household consisted of three persons, with a maximum of twelve persons (±1.43 SD). More than 80% of the respondents had a primary school degree or at least received some primary education, whereas one-eight had no formal schooling. At 55.7%, the majority of respondents are able to read and write, another fourth at least to some extent, and one-fifth of the respondents are illiterate. Household farm size from 0.1 to a maximum of 18.41 ha with an average of 1.9 ha (±1,69 SD). For the majority of survey respondents (79.6%), farming is the only source of income for the household. The remaining 20.4% of respondents generated additional income through other activities. Two-thirds of the households had no prior experience in the use of machinery for farming or processing purposes. Results show that 33.9% were experienced in agricultural technology use prior to the implementation of processing machinery.

TABLE 2 Socioeconomic information on the study population.

Variable	Frequency	Percentages
Village		
Mitumbati	273	49.2
Mibure	282	50.8
Total	555	
Age (in years)		
Below 30	62	11.2
30 to 45	184	33.2
46 to 65	185	33.3
Above 65	124	22.3
Gender		
Female	114	20.5
Male	441	79.5
Household size		
Single household	47	8.5
2 to 3 persons	258	46.5
4 to 5 persons	213	38.4
6 persons and above	37	6.6
Education		
No formal	70	12.6
Some primary	93	16.8
Primary school	355	64.0
Secondary school	37	6.6
Literacy		
Not able	110	19.8
Some reading/ writing	136	24.5
Read/Write	309	55.7
Farm size (in ha)		
Below 1	150	27.0
1 to 1.99	211	38.0
2 to 2.99	111	20.0
3 to 3.99	37	6.7
4 to 4.99	19	3.4
5 and above	27	4.9
Off-farm income		
Yes	113	20.4
No	442	79.6
Technology skills		
Yes	188	33.9
No	367	66.1

3.2 Adoption rates

Figure 2 presents the adoption rate of innovation technologies in both villages. According to the results, the highest adoption rate was recorded for PP dehullers at 78%. Further, it is shown that more than two-thirds of households adopted PP threshers. The lowest adoption rate is found for the PP flour-based products: only 47.4% of the respondents have adopted it. Moreover, as shown in Figure 2, the adoption rates for all technologies are generally higher in Mibure than in Mitumbati.

3.3 Extrinsic factors influencing farmers' adoption of processing technology

In order to identify the key extrinsic factors driving technology adoption, explanatory variables were analyzed using binary logistic regression analysis. The results of all binary logistic regression models for the adoption of PP flour products and processing technologies are summarized in Table 3, presenting odds ratios of regression coefficients (Exp (B)) and variable significance. All models were statistically significant (PP flour-based products production, χ^2 (15) =181.632, $p < 0.001$; PP threshers, χ^2 (15) =143.069 $p < 0.001$ and PP dehullers, χ^2 (15) = 76.056 $p < 0.001$). The overall percentages of model correct predictions were 73.7% for PP threshers, 74.4% for PP flour-based products, and 79.1% for PP dehullers. Thus, for all regression models, more than two-thirds of the sample data are correctly classified into the respective groups of adopters and non-adopters.

As presented in Table 3, it was found that regardless of the practice implemented, training ($p \leq 0.1$) and awareness ($p < 0.01$) of the technology tended to be the most important factors for their uptake. Households that attend training sessions are shown to be more likely to adopt the use of innovative processing technologies. As indicated through the odds ratios of coefficients, farmers who receive training in the production of PP flour-based products are 2.1 times more likely to adopt production than non-trained farmers. For the adoption of PP threshers (3.8 times) and dehullers (3.3 times), training impacts the likelihood of adoption even more. Awareness about an innovation further increased the likelihood of technology adoption by 6.7 times for PP flour-based products, 6.8 times for threshers, and 3.7 for dehullers.

Generally, the largest number of significant extrinsic influential factors were predicted by the logit model for PP flour products. It is found that the literacy level of respondents significantly influences ($p < 0.05$) their decision to produce PP flour-based products. Further, the likelihood of adopting the production of PP flour-based products increases by approximately two times ($p < 0.01$) if a respondent is literate compared to those who are only somewhat literate (Exp (B) = 0.494). An increase in farm size ($p < 0.1$) negatively affects farmers' decision to produce PP flour-based products. The odds ratio of the coefficient (0.88) indicates that for every additional hectare of agricultural land, the probability of adoption is reduced by 12%. Households that generate off-farm income ($p < 0.05$) are about 1.9 times more likely to produce PP flour products than those that are exclusively occupied with agricultural production. By possessing prior knowledge of machinery, households increase their probability of adopting PP flour production by 1.6 times compared to households without technical knowledge.

Further extrinsic influential factors were estimated through the logit model for the adoption of PP threshers. The odds for the variable age ($p < 0.1$) are 0.978, indicating that with every additional year of the farmers' age, the probability of adopting the use of threshers decreases by 1.3%. Additionally, female-headed households are 36.5% less likely to adopt PP threshers (Exp (B) = 0.635) than those led by male farmers.

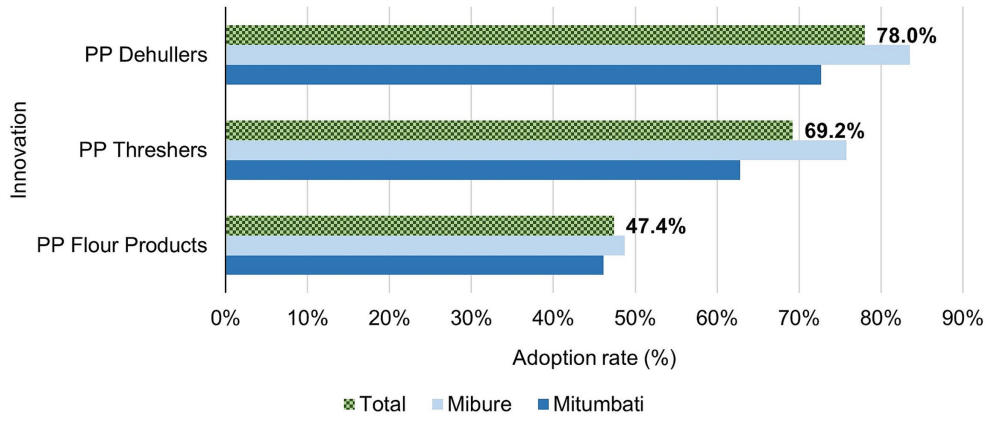

FIGURE 2
Adoption rates in the study villages.

TABLE 3 Parameter estimates of the binary logistic regression models.

Variable	Production of PP flour products		PP threshers		PP dehullers	
	Exp (B)	Sig.	Exp (B)	Sig.	Exp (B)t	Sig.
Village (Mitumbati)	1.230	0.331	1.267	0.291	1.437	0.126
Age	1.003	0.614	0.987	**0.064***	0.995	0.510
Gender	0.857	0.566	0.635	**0.099***	0.769	0.366
Household size	1,062	0.420	0.973	0.725	0.928	0.355
Education (No formal)		0.930		0.745		0.345
Some primary	0.973	0.951	0.881	0.793	0.975	0.962
Primary school	0.913	0.851	0.812	0.695	0.503	0.238
Secondary school	1.363	0.624	0.455	0.240	0.323	0.111
Literacy (Read/Write)		**0.024****		0.375		0.992
Not able	0.752	0.503	0.670	0.373	1.047	0.925
Some reading/writing	0.494	**0.006*****	0.549	0.177	1.061	0.902
Farm size	0.880	**0.053***	1.020	0.740	1.025	0.709
Off-farm income	1.868	**0.022****	0.839	0.526	0.866	0.609
Technology skills	1.633	**0.035****	0.904	0.676	0.825	0.444
Training	2.121	**0.006*****	3.792	**0.002*****	3.256	**0.010*****
Awareness	6.664	**<0.001*****	6.760	**<0.001*****	3.658	**<0.001*****
Constant	0.155	0.002	3.507	0.045	4,0.638	0.023
Omnibus Test	χ^2 (15) =181.632, p < 0.001		χ^2 (15) =143,069 p < 0.001		χ^2 (15) =76.056 p < 0.001	
Model correct prediction	74.4%		73.7%		79.1%	

***, **, * Significant at 1, 5, 10%, respectively. Coefficients of statistical significance are highlighted in the table.

3.4 Intrinsic factors influencing farmers' adoption of processing technology

A variety of different intrinsic drivers (Figure 3) and barriers (Figure 4) to the adoption of the different PP processing technologies were identified, each contributing to adoption with varying degrees. As shown in Figure 3, more than one-fourth of the respondents stated that the health benefits were the most motivating factor to produce PP flour-based products. Another 21.1% of the respondents named the generation of additional income through selling the product as an incentive. The main motivating factor for the adoption of threshers and dehullers (66.8%) was the time savings they offer compared to traditional PP processing methods. Other households (16%) preferred the improved sensory attributes of machine processed PP. Further, with similar percentages for PP processing technologies (8.6%) and PP flour-based products (7.9%), the longer shelf life of processed goods motivated households' adoption decision.

The largest factor that prevented the households from producing PP flour-based products (46.3%) and PP processing technology (18.0%) was a lack of knowledge. Further, households faced problems

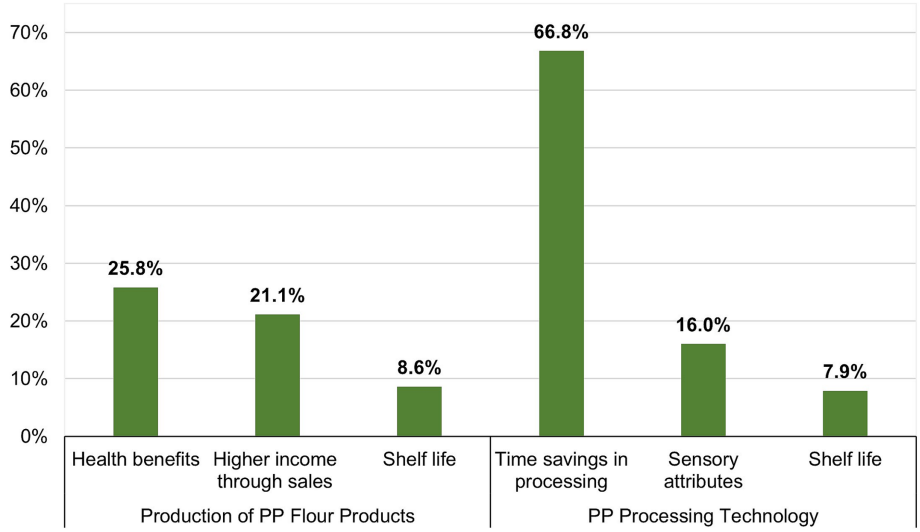

FIGURE 3
Motivating factors influencing the adoption of innovative pigeon pea processing technology and products.

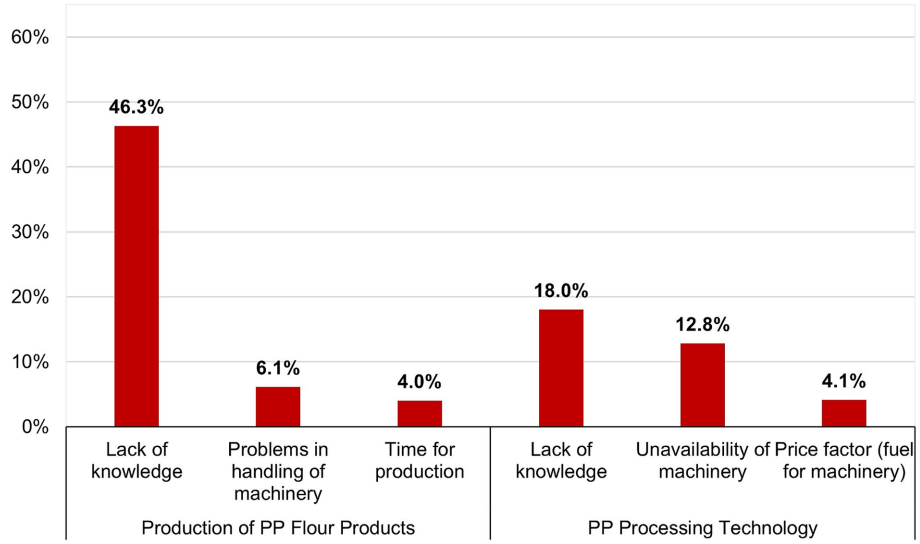

FIGURE 4
Hindering factors influencing the adoption of innovative pigeon pea processing technology and products.

with the handling of machinery for PP flour products production (6.1%) or perceived the production of these products as too time-consuming. Other barriers to the use of processing machinery were their unavailability (12.8%) and input prices for fuel (4.1%).

4 Discussion

This study aims, first, at assessing the adoption rates of innovative PP flour-based products and processing technologies in two villages (Mitumbati and Mibure) in the Lindi Region of Tanzania and, secondly, understanding the extrinsic and intrinsic drivers of their adoption. The examined processing technologies – PP threshers and dehullers – were well received by the study population, whereas the adoption of innovative PP processing, like flour-based products, was significantly lower. Overall, the most significant extrinsic factors influencing the adoption of innovative processing technologies and products were training and awareness of the technology, irrespective of the agricultural post-harvest innovation examined. The use of processing machinery was influenced by fewer external factors than the uptake of the new production processes for PP products. A deeper insight into farmers' perceptions, knowledge, and attitudes shows that technology adoption is mainly driven by health benefits assigned to the products and time savings of machinery use; simultaneously it is hindered by a lack of knowledge about the innovations as well as their unavailability. Farmers considered these factors as more important in relation to their adoption decision than financial incentives and barriers.

It is found that extension measures, like training and awareness building, are critical measures for adoption. Despite an implemented training program for the target households, it is found that the most important factor hindering the adoption of technologies is a lack of knowledge about the innovations. These findings are in line with the results of Singh and Yadav (2014) and Kragt et al. (2017), both finding that a knowledge gap impedes adoption, especially in relation to risks and uncertainties in farmers' production outcomes. Rogers (2003) states that most people refrain from innovation adoption due to a fear of unknown future risks. This further implies that farmers in the study region may perceive that they require more knowledge and skills for technology adoption, for instance in order to reduce risks related to the input of goods or capital (Lalani et al., 2016). The knowledge gap also leads to other assumptions that farmers expressed as barriers to the use of technology, such as problems in handling the machinery for PP flour products production. Another misconception is that farmers perceived the production of PP flour products as too time consuming, although the production time of PP flour products is almost equal compared to traditionally used practices. Thus, misinformation and insufficient knowledge underlie farmers' subjective interpretation of reality, negatively affecting farmers' adoption decisions. This is consistent with a broad range of evidence; in particular, suggesting farmers' attitudes and their negative perceptions are major constraints to technology adoption (Adesina, 1993; Kulshreshtha and Brown, 1993; Mottaleb, 2018). In line with this finding are the results of this study, which identified training and awareness as most significant extrinsic factors, directly influencing farmers' intrinsic perceptions, knowledge, and attitudes towards innovation. These findings are in line with the results of Parwada et al. (2010), who find that the adoption of agroforestry technology is significantly higher for trained farmers. Okoedo-Okojie and Onemolease (2009) find that contact with extension agents increases the adoption of Yam storage technologies by 79%. Training in the use of agricultural innovation plays an important role in capacity building and strengthens the farmer's knowledge (Maguire, 2012). As it can be seen as a prerequisite for awareness that farmers are exposed to the use of an innovation through training, users, or another source of information, the variable integrates the impact of informal information dissemination on adoption (Halloran et al., 2021). The project implemented one thresher and one dehuller per village. Therefore, these machines were shared at the village level and individual use was limited in time. Due to high demand of farmers, threshers and dehullers were often occupied and thus not equally available to every individual farmer (unavailability).

In line with the findings of Voh (1982) and Weir and Knight (2004), this study finds that the likelihood of adopting the production of PP flour products is higher for literate farmers than for only somewhat or illiterate farmers. Since recipes involve multiple steps, it is important to remember them accurately. Literate farmers are at an advantage, as they have the possibility to write down recipes and new production processes, such as making PP flour noodles, where it might be important to keep a record of the process until it is internalized. Moreover, this study finds that farmers generating additional income besides farming are more likely to adopt the production of PP flour-based products, which is consistent with the findings of Fernandez-Cornejo et al. (2007) who find that the adoption of improved soybean varieties is positively impacted by the generation of off-farm income. Feder et al. (1985) argue that off-farm income may help finance initial fixed costs. As for value added products, like Maandazi, Bhajia, Chapati, or biscuits, farmers must purchase additional ingredients (oil, wheat, sugar), all of which must be financed by their own resources. Farm size negatively affects the adoption of PP flour-based products. Although a variety of studies find that farm size positively affects technology adoption (Okoedo-Okojie and Onemolease, 2009; Raghu et al., 2014; Hu et al., 2022), the literature review of Feder et al. (1985) arrives at mixed results: size can act in both directions. Ntshangase et al. (2018) argue that larger farms also have higher labor requirements, which may discourage farmers from adopting no-till conservation agriculture as it takes additional time and labor resources. Farmers' technology skills positively affect the production of PP flour-based products. Several studies find that the farming experience of farmers positively impacts technology adoption (Adetunji, 2009; Okoedo-Okojie and Onemolease, 2009; Ajibesin et al., 2019). Pignatti et al. (2015) report that an individual's skillset is a crucial factor for technology adoption. Agor et al. (2020) find that the probability of uptake for value adding sweet potato processing technology is higher for individuals with prior experience in processing. As PP flour production requires the use of a miller, farmers who are already familiar with technical equipment may be more likely to have the confidence to use the machine. The results of this study indicate that older age negatively affected farmers' probability of adopting the use of threshers. Therefore, older farmers at the study sites are less likely to use threshers than younger farmers. Based on our field observations, the reasons for this phenomenon may be attributed to heightened risk aversion among elderly farmers in the study region, possibly influenced by concerns about potential failures or losses associated with the adoption of threshers. Moreover, they might prefer the traditional farming methods they have used throughout their long farming careers. Additionally, a lack of training and education in modern farming techniques might hinder their ability to use these tools effectively. Kinyangi (2012) argues that older farmers may be hesitant to try a completely new practice since they have invested several years in perfecting the traditional method. These findings are consistent with the results of Okoedo-Okojie and Onemolease (2009), which find that older farmers tend to be less willing to take risks than younger farmers. Another reason might be that old age is often connected to poor health conditions. Abdulai and Huffman (2014) state that households may lose valuable labor due to illness and, therefore, poor health acts as a barrier, leading to low adoption rates. However, as the use of threshing machines in this study is less time and labor intensive than the traditional processing method, a lack of knowledge of elderly farmers might also have contributed to low adoption rates. For the use of threshers, the results show that households that have a male household head are 1.6 times more likely to use the threshers for PP processing than those led by female farmers. These findings are in line with studies from Doss (2001a) and Kumar (1994). Doss (2001b) report that adoption decisions are not solely connected to gender, but can rather be related to other gender-linked factors, like restrained access to resources (e.g., extension contacts, education, land size, labor force).

In this study, health benefits were one of the major enabling intrinsic factors for adoption. Improving someone's health turns out to be a motivating factor to produce PP flour products. The same applies to the factor of a longer shelf life, which is also mentioned as a motivating factor for all innovations. These findings are consistent with the results of Mellon-Bedi et al. (2020), who find that improvements

in household dietary diversity are an enabler for the adoption of sustainable intensification practices in Ghana. Further, Greiner and Gregg (2011) report that farmers' decisions are motivated by the active pursuit of personal and family well-being. This underlines that knowledge building through training measures and /or information dissemination surrounding the use of processing innovations is a crucial element for adoption. As nutrition education is an important part of the training curriculum, a large proportion of the farmers had knowledge about the health benefits processed goods provide. Sensory attributes of processed pigeon pea products are motivating factors for the adoption of processing machinery. This finding supports Mellon-Bedi et al. (2020), who find that fulfillment of farmers' personal satisfaction is an enabler for adoption. As farmers were able to taste the products produced with innovative processing technologies, they were directly rewarded with their benefits in terms of sensory attributes. This is in line with Rogers (2003), who states that the degree to which an innovation provides tangible results is an important factor in its adoption. Moreover, as perceptions about taste can be different for every farmer, these findings highlight the importance of subjective opinions within the adoption process. For PP processing machinery, farmers considered time savings through reduced labor as a main motivating factor for adoption. This is in line with the concept of the "relative advantage" of innovation according to Rogers (2003), which the author determines as one of the elements impacting the rate of adoption. Thus, farmers are more likely to adopt new agricultural technology if they perceive that it offers more advantages than the current method while also saving them time and effort.

The results indicate that knowledge about the general use, the benefits, the risks, and related uncertainties are among the most important intrinsic factors shaping adoption decisions. This implies that well-adapted training interventions that sufficiently educate farmers have the potential to increase adoption rates. Farmers in the study region were also mainly motivated, among other factors, by the health benefits the processed goods provide. As nutrition education about the health benefits of PP products was part of the training curriculum, scaling up nutrition education could provide further incentives to adopt the improved technologies. To overcome the knowledge gap, it remains important to promote knowledge transfer on agricultural innovations and to explicitly communicate their benefits through training sessions. Based on the findings of this study, it is important to strengthen inclusivity within the training measures, especially regarding the integration of illiterate farmers, but also in terms of measures that explicitly target women or older farmers. Moreover, further incorporating other actors throughout the value chain, such as supermarkets and local media outlets, will increase accessibility to information, thus raising knowledge and awareness levels; this bears great potential to improve adoption on the ground. Further research on extrinsic and intrinsic adoption relevant factors can help to identify opportunities and challenges along the adoption process, thus providing an important basis to tackle existing problems and design future implementation processes for agricultural innovations in a sustainable and context-specific manner to address food and nutrition security.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the National Institute for Medical Research, Dar es Salaam, and the Ministry of Health, Community Development, Gender, Elderly and Children in Dodoma, Tanzania (NIMR/HQ/R.8a/Vol.IX/3040) and carried out according to the guidelines laid down in the 'Declaration of Helsinki'. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

MS and CR contributed to the conception and design of the study. CR raised the funds. ZM, HM, and JK collected the data. MS, NK, and CM analysed the data. MS wrote the first draft of the manuscript and CR, NK, CM, and KL critically reviewed and edited the manuscript. All authors contributed to the manuscript revision, read and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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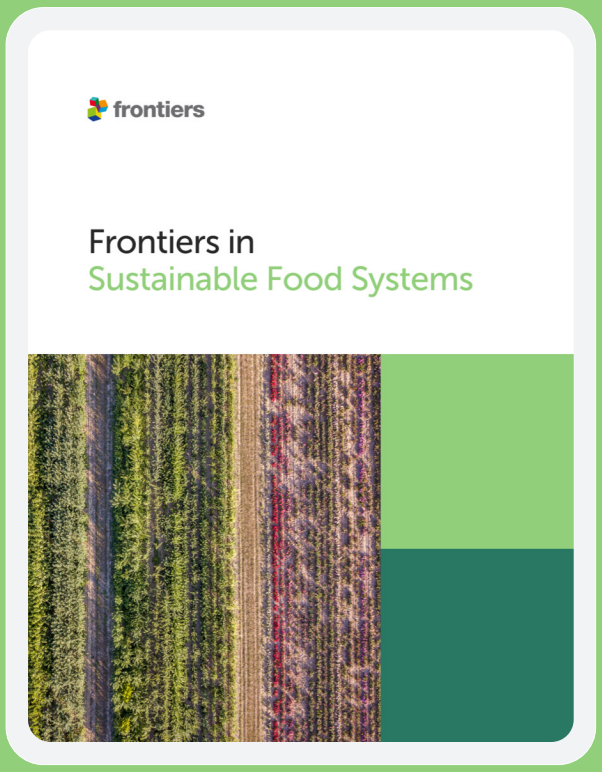

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