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# Keeping Up With Rising (Quality) Demands? The Transition of a Wild Food Resource to Mass Market, Using the Example of Baobab in Malawi

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The importance of wild food resources, particularly from our forests, is increasingly recognized in the context of food systems transformation and derived products are increasingly also entering modern food supply chains. The transformation of a wild, solely traditionally used resource to a product available in retail, however, has consequences, not all of which are currently well understood. Using the rapidly increasing commercialization of baobab fruit products in Malawi as a case study we, therefore, aim to shed light on aspects such a transformation may have on product quality and supply chain organization. Using a mixed-methods approach a total of 68 baobab value chain actors targeting either formal or informal markets were interviewed, focusing on perceived baobab quality characteristics as well as linkages across the value chain, concurrently collecting product samples if the interviewees had these at hand. The baobab supply chain was shown to have elongated in recent years, with a variety of actors now active on the scene, including baobab collectors, a variety of traders often directly picking up baobab resources at source, microenterprises producing baobab ice lollies for informal markets, or more formal juice processors targeting retail outlets. A broad variety of harvest, storage, or processing practices was observed and product quality differed widely, whereas mycotoxins were detected in two of the analyzed samples. Storage of baobab products can last several months with harvesting activities peaking in April, yet sales dominating in the hot months toward the end of the year. Dryness was commonly identified as the most important quality indicator, but other factors such as cracks in the shell were more heavily disputed amongst different value chain actors. Although different quality standards have to be observed to be able to sell in formal retail outlets, risks of low-quality baobab entering formal retail outlets remains with the majority of more formal baobab processors obtaining their raw material via informal pathways. There is a dire need to strengthen the institutional framework and enabling environment to foster the best-possible integration of forest resources into prevailing agri-food systems and enable the production of high-quality products for both the formal and the informal sector.

**Keywords: non-timber forest products, baobab (*Adansonia digitata* L.), commercialization, market development, supply chain organization, product quality, mycotoxins**

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## INTRODUCTION

For most of our existence humankind has been dependent on wild food resources with hunting and gathering being the dominant livelihood strategy. The domestication of plants and animals for food with all its consequences, estimated to having started ∼12,000–11,000 years ago, can be regarded as one of the most significant cultural and evolutionary shifts for humankind (Larson et al., 2014). Yet even today, despite the fact that most of our food resources nowadays come from only few cultivated sources, wild foods, particularly from our forests, play an important, although often unseen, role for our subsistence and consumption needs (Delang, 2006; Bharucha and Pretty, 2010). The majority of rural households still collect wild foods across Asia, Africa, and Latin America (Hickey et al., 2016), and even in Europe it is estimated that ∼a quarter make use of non-timber forest products (NTFPs) such as fruits, mushrooms, or berries (Lovri et al., 2020). These resources often are important providers of micronutrients (Barany et al., 2004; Bvenura and Afolayan, 2015; Smanalieva et al., 2020) and higher tree cover has been associated with higher dietary diversity (Ickowitz et al., 2014).

As such, the role forests and trees can play in contributing to food and nutrition security is increasingly being recognized (Sunderland, 2011; Chamberlain et al., 2020) and interest concerning the collection, processing and consumption of wild foods is rising (Pieroni, 2021). This "re-discovery" of wild food resources is fostered by the increasing appreciation for natural, healthy, indigenous foods on the one hand (Grunert, 2017), yet also the diverse possibilities these foods can offer from a nutritional, but also commercial point of view (Aworh, 2015; Nitcheu Ngemakwe et al., 2017). With such potential increasingly being identified and acknowledged (van Wyk, 2015; Neri-Numa et al., 2018), selected nutritious NTFPs are now available on high-value domestic and international markets with demand expected to rise, although many are still only being used traditionally.

Resources originating from the baobab tree (*Adansonia digitata* L.), which commonly occurs in semi-arid to arid savannahs and savannah woodlands of sub-Saharan Africa (Wickens and Lowe, 2008), are a typical example in this regard. Products derived from its fruits are, besides their traditional use, increasingly available both on the international (Gebauer et al., 2014) as well as domestic markets, where a transition from solely informal use to higher-value market segments has been observed (Darr et al., 2020). The fruit offers numerous application possibilities (Gebauer et al., 2016); especially due to its outstanding nutritional properties containing high levels of Vitamin C, dietary fiber, minerals, and phytochemicals (Chadare et al., 2009), associated health benefits (Coe et al., 2013; Braca et al., 2018), a potential to combat micronutrient deficiencies, coupled with its favorable properties from a food technology point of view. The fruit pulp being naturally dry when the fruit is ripe can easily be added to and enrich other foods (Gabaza et al., 2018; Mounjouenpou et al., 2018; van der Merwe et al., 2019) and an increasing number of products are being developed and investigated, particularly in the health food segment (Mpofu et al., 2014; Alba et al., 2020; Darr, Dumenu, Gebauer, Kasulo, Kleinke, Meinhold, forthcoming). Since the species is highly prevalent in areas with high food and nutrition insecurity, yet its full potential remains underexploited (Assogbadjo et al., 2021), these aspects are of particular relevance.

Nevertheless, the transformation from a wild, informally used resource to a product available in formal food markets has consequences, not all of which are currently well understood. Previous research has highlighted the risk of overexploitation of wild food resources and negative environmental implications (Ticktin, 2004; Brites and Morsello, 2016), which, coupled with increased demand may stimulate more active management of the resource as well as cultivation and domestication processes (Wiersum et al., 2007; Bharucha and Pretty, 2010; Muriuki et al., 2012; García-Amado et al., 2013; van Wyk and Prinsloo, 2018). This holds true for the baobab tree as well, for which the risk of overexploitation has already been acknowledged (Buchmann et al., 2010; Sanchez, 2011) and its management has already had effects on the tree's distribution patterns, with baobab being more prevalent in areas associated with human habitation (Dhillion and Gustad, 2004; Duvall, 2007; Venter and Witkowski, 2010). These findings may be an indication that baobab saplings close to villages are on the one hand taken care of by local populations, yet on the other hand also preferably exploited in contrast to resources further afield (Assogbadjo et al., 2021). Overall, although baobab is not yet being cultivated *per se*, the tree has been identified as a priority species for domestication (Sanchez et al., 2010; Gebauer et al., 2016). However, other aspects resulting from the more formal integration of wild food resources into our food systems in today's society as opposed to domestication processes thousands of years ago, are less understood, including food safety issues or possible supply chain implications. Therefore, the main aim of this manuscript is to shed light on possible implications a rapidly establishing NTFP industry based on wild in contrast to agricultural resources may have on product quality and supply chain organization, using the rapidly increasing commercialization of baobab fruit products in Malawi as a case study.

## CONCEPTUAL FRAMEWORK

When NTFPs transition from subsistence to commercial use an increasing number of actors and institutions naturally become involved: originating from the NTFP harvesters other stakeholders such as processors, traders and consumers further afield join the system and become increasingly interlinked, influenced by a variety of market and regulatory institutions including policies, standards or social norms. To be better able to grasp and assess such complex processes in times where food systems in developing regions can be considered to rapidly change anyhow (Reardon et al., 2019), we apply an innovation system perspective, which acknowledges the importance of interconnections between the many different actors and factors involved. It has been deemed a useful approach both in agriculture (Klerkx et al., 2012) and in forestry (Rametsteiner and Weiss, 2006) to help understand emerging innovations and industrial change. As such, innovation systems aim to provide a holistic view on innovation processes, identifying the various

actors and the complex relationships between them, as well as influencing factors affecting the introduction and uptake of novel technologies or practices into an economy (Botta et al., 2015). In doing so the approach aligns not only technical, but also social, institutional, and organizational dimensions (Kilelu et al., 2013).

In our approach (**Figure 1**) we particularly emphasize the food value chain actors present in the system, since on the one hand they play a key role in innovation in food chains (Bijman and Bitzer, 2016) and on the other hand NTFP commercialization has been shown to commonly originate from bottom up approaches (te Velde et al., 2006; Meinhold et al., 2022). Actor-based conceptualizations of value chains including all stakeholders active from production to consumption have also been deemed the most coherent approach for value chain development (Donovan et al., 2015). In this connection, a closer vertical integration amongst value chain members is generally seen as beneficial, e.g., it has shown to generally improve business performance (Frohlich and Westbrook, 2001; Flynn et al., 2010), and in a food context it is increasingly being acknowledged that an enhanced vertical coordination between the different actors involved in the chain in question is vital for achieving higher product qualities (Bijman and Bitzer, 2016).

Achieving the latter is seen as increasingly important for economic success due to rising consumer demand for high quality products on the one hand and the increasing number of food quality standards or safety protocols imposed by public and private actors such as large retailers or processors on the other hand (Swinnen and Maertens, 2007; Trienekens and Zuurbier, 2008). Domestic markets in developing countries are no exceptions in this regard where food value chains are currently undergoing rapid transformations along these lines (Swinnen and Maertens, 2007). Yet due to the fact that smallholders in developing countries often lack resources or an adequate enabling institutional environment for quality improvement (Royer and Bijman, 2012), chain actors in these markets often still act more independently from each other and, consequently, quality improvements are more difficult to achieve (Abebe et al., 2016). This is potentially enhanced by varying quality perceptions of value chain actors depending on their position in the chain (Ruben et al., 2007), as well as sparse information exchange on quality aspects (Abebe et al., 2016). Consequently, alignment between actors is not sufficiently based on quality considerations and low-quality products may enter the market. This can also help explain the increasing differentiation in food chains depending on the quality demanded by final consumers (Bijman and Bitzer, 2016). For instance Jaffee et al. (2011) distinguishes six different markets representing different quality requirements, ranging from local wet-markets to high-end

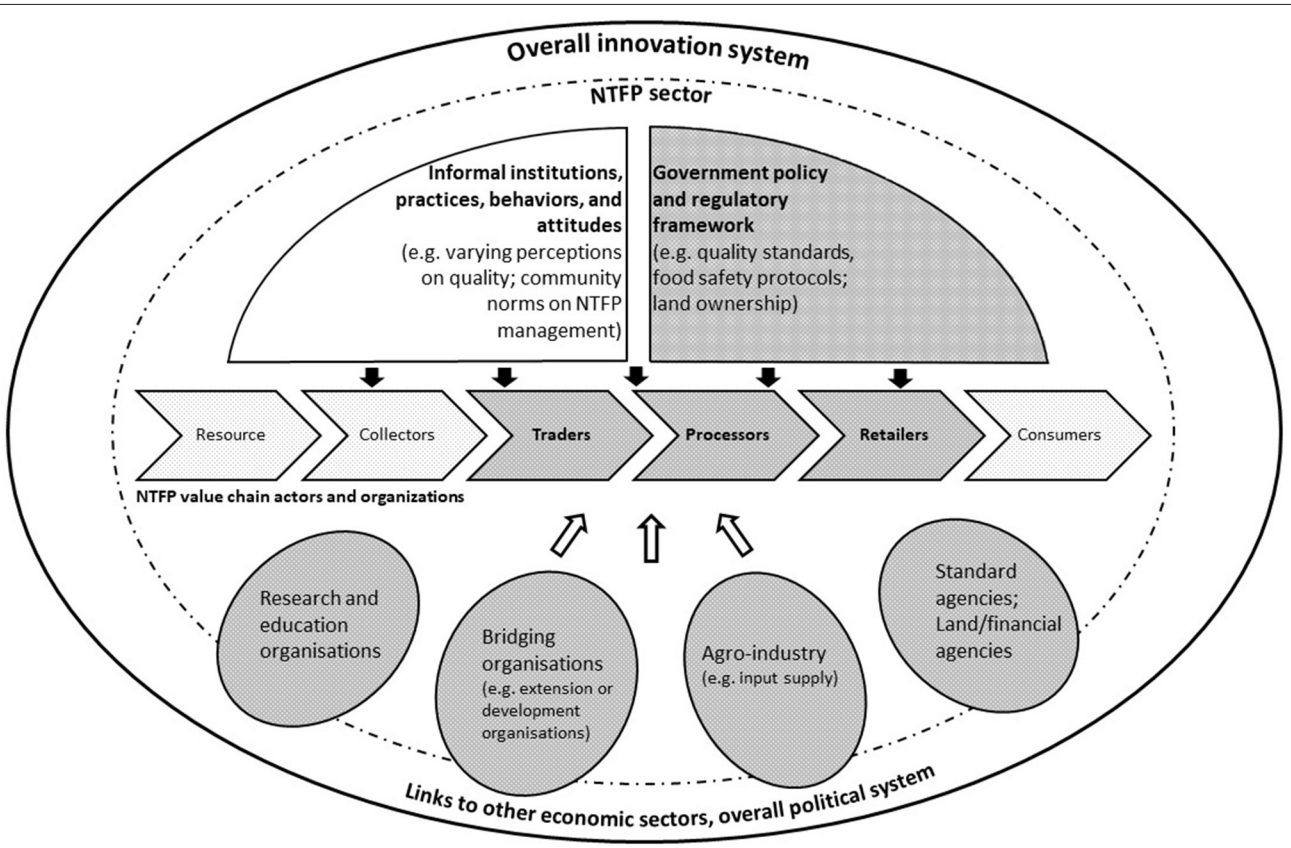


**FIGURE 1 |** Overall conceptual framework. Transitioning from NTFP subsistence to commercial use, further actors and institutions gain importance (highlighted in darker shade).

markets in importing countries. In order to understand a respective product quality in a given context it is, therefore, necessary to understand the respective roles and motives of all chain actors (Bijman and Bitzer, 2016).

As such, however, it has to be acknowledged that quality itself is quite an elusive concept that cannot easily be defined (Reeves and Bednar, 1994). The quality of a product is often broken down to different quality attributes, which in turn can be aggregated to intrinsic (e.g., physical product properties such as color or shape) vs. extrinsic quality attributes (e.g., price, production methods), as well as search (attributes known at the moment of purchase), experience (attributes only known after consumption), and credence (quality attributes that cannot be verified through search or experience) attributes (Oude Ophuis and van Trijp, 1995). Thus, quality can encompass both objective, measurable aspects such as the adherence to certain standards as well as subjective measures, which may differ depending on the perception of different people (Reeves and Bednar, 1994; Oude Ophuis and van Trijp, 1995; Ruben et al., 2007; Bijman and Bitzer, 2016). A more uniform interpretation of quality along these lines amongst different actors involved in a production process can help advance product quality achieved.

## STUDY AREA AND METHODS

Data was collected from five districts in Malawi, namely Chikwawa, Mangochi, Salima, Lilongwe, and Blantyre between July and September 2018. These districts were purposively selected based on a literature review and interviews with key informants, representing the centers of baobab fruit commercialization in Malawi, including both rural areas with high prevalence of baobab trees and fruit extraction rates (Sanchez, 2011) as well as semi-urban and urban baobab trading and processing hubs. A mixed-methods approach was employed to study quality aspects and supply chain organization in the recently formed baobab value chains. Data was collected from in total 68 value chain actors (**Table 1**) targeting either formal or informal markets, including baobab collectors ($n = 21$), traders in rural, semi-urban, and urban markets ($n = 21$), processors ($n = 16$), retailers ($n = 5$), as well as members from the broader institutional environment ($n = 5$), using a structured questionnaire adapted to each stakeholder group. Questions focused on stakeholder's perceived baobab quality characteristics depending on their products handled (fruits, pulp, and/or powder) as well as their respective linkages across the value chain. Individual respondents were selected using convenience sampling and snowball sampling with support from the respective district forestry officers.

Concurrently, a total of 77 baobab product samples were collected from the interviewed value chain actors if at hand (28 fruit, 34 pulp-on-seed, and 15 powder samples). Besides basic data on harvesting and storage times, pulp texture and color, or visible mold appearance, all baobab samples were subjected to external laboratory analysis, focusing on mycotoxin (aflatoxins B1, B2, G1, and G2) and Vitamin C levels. Mycotoxins, toxic secondary metabolites of fungi, were selected as quality indicator, since they are highly stable components and they are associated with serious health as well as economic implications, especially in many African countries with effective strategies to control levels lacking (Kebede et al., 2020). Mycotoxin contamination can occur during all stages of the production process both pre- and post-harvest. Vitamin C, an essential micronutrient we must acquire from dietary sources, was chosen as quality indicator since it is one of most highly praised nutritional properties in baobab fruits, even if its amount can be greatly affected by aspects such as harvesting period, storage time and conditions, amongst others. Standard laboratory procedures were employed to detect these components in the product samples, LC-MS/MS for mycotoxin (Di Diana Mavungu et al., 2009) and HPLC/Fl for Vitamin C analysis (Spínola et al., 2014).

**TABLE 1 |** Overview of interviewed stakeholders and samples obtained.

| | No of product samples | | |
|---|---|---|---|
| | **Fruit** | **Pulp** | **Powder** |
| **Informal VC members ($n = 46$)** | | | |
| Informal collectors ($n = 16$) | 8 | 5 | - |
| Traders ($n = 21$) | 15 | 21 | 7 |
| Informal processors ($n = 9$) | 1 | 4 | 1 |
| **Formal VC members ($n = 17$)** | | | |
| Formal collectors ($n = 5$) | 2 | 2 | - |
| Formal processors ($n = 7$) | 2 | 2 | 2 |
| Retailers ($n = 5$) | - | - | 5 |
| **Broader institutional environment ($n = 5$)** | n/a | n/a | n/a |
| Total no of product samples | 28 | 34 | 15 |

The data was triangulated by market observations and a review of relevant literature. The study was approved in advance by the Malawi National Commission for Science and Technology (protocol number P.02/18/247), and all subjects gave their informed written consent for inclusion before participating in the study. Qualitative interview data were analyzed by content analysis, whereas quantitative interview as well as the sample data were analyzed using IBM SPSS Statistics (Version 26.0). Descriptive statistics were applied to compare different aspects of value chain actors as well as baobab products in the study area, such as quality characteristics, harvesting and storage times, or supply chain linkages. Depending on data type, different comparative statistical analysis were applied, including Pearson's chi-squared test, independent samples *t*-test, or one-way ANOVA to determine any statistical significance.

## RESULTS

### Historical Formation of the Baobab Processing Sector in Malawi

Baobab commercialization in Malawi has gone through a rapid development process in the recent decades. Historically, baobab collection and use was limited to the household level, with fruits—if utilized at all—only being traditionally processed with simple equipment and then used as an ingredient mainly in

porridge or eaten as a snack (Bennett, 2006; Welford et al., 2015). Since then, baobab processing businesses have mushroomed in Malawi and the manufacture of baobab products such as fruit juices, ice-lollies, sweets or cosmetics, has become a common business with products being widely available in both formal as well as informal domestic markets (Darr et al., 2020).

The origin of these developments can be traced to a development project in Malawi's Neno district implemented by the Wildlife and Environmental Society of Malawi between 1996 and 2006. Supported by the German development sector the project was the first in Malawi aiming to professionalize baobab juice production and commercialization whilst improving livelihoods and preserving surrounding forests. The community-owned company "*Village Hands*" founded within the project timeframe was enabled to produce and supply bottled baobab juice to major retail markets across Malawi (Kambewa and Utila, 2008). Whereas this enterprise did not last long beyond the project's timeframe, the initiative stimulated other, both formal and informal, baobab business operations and from ∼2006 onwards trade in baobab juices and ice-lollies became apparent in Malawi's urban centers, leading to a rapid increase in demand for the fruit (Welford et al., 2015). While the collection of baobab fruits as well as juice and ice-lolly manufacturing can provide much needed income for thousands of households across the country, it increases the risk of overexploitation of the resource and little natural regeneration has already been observed in some areas of Malawi (Sanchez, 2011).

Additionally, with baobab slowly gaining international recognition particularly in the health foods segment (Bennett, 2006), Malawi was, building on the experiences in the domestic market, also at the forefront considering export of baobab resources. This was associated with an increasing professionalization, including the development of specialized processing machinery, quality control procedures, supply chain management strategies to ensure traceability, as well as schemes to ensure sustainable harvesting practices such as baobab stock inventories and harvesting quotas, as well as certification schemes (Meinhold et al., 2022). These efforts were strongly linked to activities of PhytoTrade Africa, a regional trade association aiming to improve rural livelihoods by developing a sustainable natural products sector, which had added baobab to their list of high-potential species from its inception in 2001 (ICTSD, 2007). Malawi quickly became one of the pioneers in exporting organically certified baobab fruit powder, whereas the exporting enterprise and PhytoTrade member "*TreeCrops*", founded 2006, managed to reach a maximum production capacity of 125 t powder/year, while integrating ethical bio-trade principles into its supply chain.

However, the Malawian baobab exporting sector collapsed in ∼2016, not even 10 years after PhytoTrade had facilitated the necessary novel food approvals to enter European and US markets (EC., 2008; FDA., 2009). Unmet microbiological quality parameters were the main reason for the demise, linked to factors including a season of drought and premature fruit harvesting due to economic hardship, high local demand, and increased difficulties in rigorously tracing the supply chain. The collector association set up for the export market has since then refocused its activities to providing baobab to the main local baobab juice manufacturer in Malawi.

## Baobab Value Chains in Malawi: Activities and Stakeholders

The main actors of baobab value chains in Malawi include baobab collectors, traders located in rural, semi-urban as well as urban areas, informal processors, predominantly for the production of baobab ice-lollies, more formal juice processors, and retailers (**Figure 2**). Besides juice, ice-lollies, and traditional, direct consumption, baobab fruits were reported to be used for the production of jam, sweets, and alcoholic beverages, whereas the seeds were occasionally processed into oil for further use in cosmetics or roasted and used as a coffee substitute.

Located within the baobab-growing regions in Malawi, most baobab collectors, over 80 % of which were male, <40 years old and with only primary education, pursued mixed livelihood strategies, with baobab providing a seasonal income opportunity. The main harvesting months for baobab were reported to be April to June, yet some collectors harvested as early as February and as late as October. Fruits were most commonly removed from the tree by using long sticks with attached hooks, either from the ground or after climbing the tree, which occasionally were prepared for this activity by inserting timber sticks into its thick bark, thus forming a ladder. The majority of collectors reported to further dry the fruits in the sun for up to 2 weeks after harvest, before moving them into the house for storage. Sale of baobab fruit then occurred almost immediately or after 1–2 months additional storage. Customers were mainly traders (56.3 %), informal baobab processors (25 %), or both (18.8 %). In over two thirds of cases buyers directly traveled to the collectors to obtain baobab resources, sometimes even providing an advance payment to secure the fruit. Fruits were then typically cracked directly at source, which was carried out outside on a mat by using a stone or a piece of wood after which the fruit pulp gets extracted. Collectors also reported to sometimes, especially later in the season, directly deliver fruit to baobab processors, rural markets or even hire trucks to bring baobab to urban centers in Lilongwe or Blantyre in order to obtain a better price.

Traders of baobab resources, 76.2 % of interviewed were male, 71.4 % between 18 and 40 years old, 60.0 % only primary school level, are ubiquitous in Malawi. Most commonly traders dealt with both the whole fruit and the extracted pulp-on-seed (52.4 %), yet baobab was often only part of the trader's portfolio. Traded baobab originated not only from the various baobab-growing regions in Malawi, some traders even imported from neighboring countries such as Mozambique or Tanzania due to the high demand. Purchase of baobab fruit peaked between April and June, with ∼half of the traders obtaining the baobab directly from collectors, especially early in the season when stocks ran low. Fruits were either cracked directly at source or at the marketplace, whereas the fruit pulp was occasionally dried further, especially when wet. Baobab resources were stored throughout the year by 66.7 % of interviewed traders, with others running out toward the end of the year—since baobab sales were reported to typically peak in the hot months between September

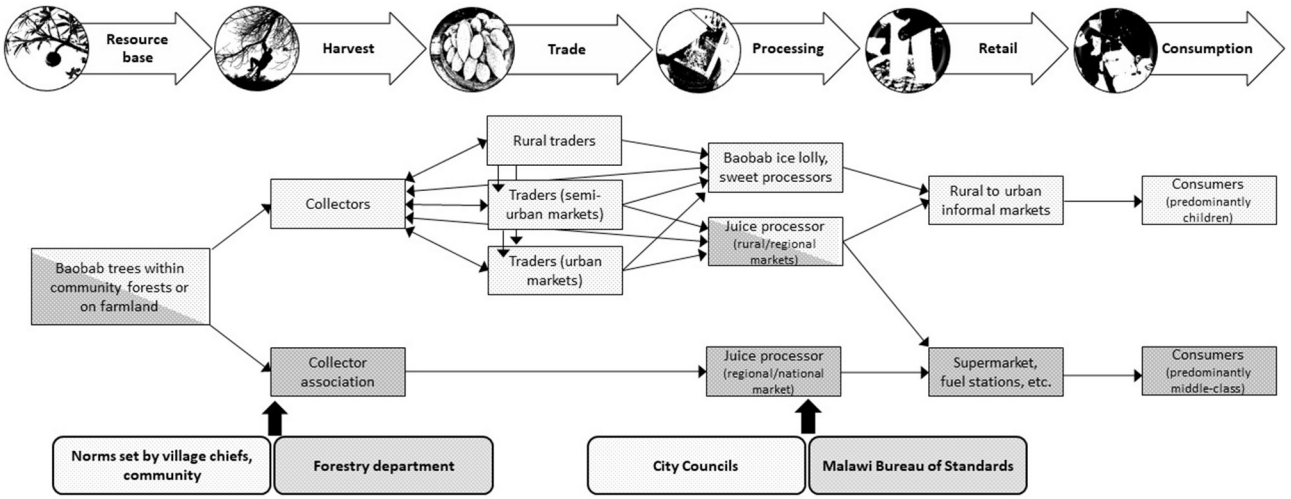


**FIGURE 2 |** Main stakeholders and channels in the *Adansonia digitata* L. value chain from Malawi. The dominant informal commercialization pathway is depicted in a lighter shade, the newly formed formal commercialization pathways in a darker shade.

and December, when most informal baobab processing takes place and best prices can be achieved.

The main processed baobab product available on informal markets were baobab ice lollies, yet occasionally also baobab juice and sweets were manufactured. Processors were most commonly one-person microenterprises, whereas women produce and sell baobab products for an additional income opportunity, occasionally assisted by family members, most commonly their daughters. 66.7 % of processors interviewed went up to secondary school and 55.6 % were between 40 and 50 years old. The processing of baobab ice lollies typically took place in the kitchen at home, whereas baobab fruit pulp was mixed with water and boiled for anything between 5 and 30 min. This mixture then gets filtered to remove the seeds and other particles, after which sugar, food coloring or extra artificial flavors are added. The resulting mix is filled into small plastic tubes and frozen for 1–2 days before selling, for which the ice lollies were put into cooling boxes. The production process is seldom modified, only quantities adjusted depending on the season with peak sales occurring in the hotter months of September and October; yet 77.8 % produced and sold ice lollies all year round. To achieve this, processors stored baobab resources purchased during the season either from collectors, traders, or both at their home, whereas storage of pulp was preferred. Since the target customer were (school-) children, ice lollies were most commonly sold close to schools.

Besides this informal pathway, a small, more formalized baobab sector has also evolved in Malawi. One baobab collector association exists, which was originally established for the export market and after its demise refocused its activities on supplying the major domestic baobab juice manufacturer. In total 178 predominantly male baobab collectors were registered with the association during the study period, who can supply baobab to local depots, after having attended a training, focusing on adequate harvesting, storage and pre-processing practices observing quality control measures in all the steps including picking only the ripened and non-cracked fruit from the ground. After harvest, which took place in May/June in the season under investigation, fruits were reported to be further dried on special drying systems above ground to ensure air circulation and brought to the respective depots as soon as the association announced it at the end of July. Pre-processing occurred inside the depots, 11 of which were active during the study with each serving 4–6 villages. For this activity, registered collectors follow certain hygienic guidelines such as wearing an apron, covering the hair, or washing hands before cracking fruits with a machete. The extracted pulp then gets weighed and the amount recorded together with the name of the collector to ensure traceability. The collectors receive a fixed, above average price, which is negotiated on a yearly basis (240 MK/kg baobab in the study period). Once the depot is full, the pulp gets picked up and brought to Lilongwe for further processing, while the collectors receive their payment ∼2 weeks after that. The final processing, first into powder and then into juice, is carried out at a central factory in the capital using specialized equipment. Approximately 60 t of baobab pulp are processed each year into powder which is then stored to be able to produce baobab juice throughout the year. For the latter, water and baobab fruit powder are mixed, heated via electrical means following a standardized temperature scheme, before adding the remaining ingredients, i.e. sugar, sweetener, and preservatives, letting the mixture cool and package into bottles.

Other more formalized baobab processing enterprises active in Malawi obtained their baobab resources either from unorganized collectors or traders, who often directly went to the respective central processing facility to sell their resources. In this case, baobab was typically obtained within the season between March and September and stored for up to a year to ensure continuous production. Juice was the main product, although jam was also commonly manufactured, with most processing operations not solely being specialized on baobab. Manufacturing

takes place at a central facility, but, in contrast to the operation illustrated above, all processes are carried out manually, using firewood for heating purposes and controlling the temperature and other processes by simply means such as observation and using one's senses instead of technical equipment. However, ingredients used were similar, with only slight variations in quantities used, preservatives added, or the additional use of sweeteners and thickener. Overall, business schemes varied widely across more formalized baobab processing operations in Malawi, with both cooperatives as well as (family) enterprises active on the scene, the former often having been assisted by NGOs to set up their operations.

In any case, manufactured baobab products originating from these pathways were sold in more formal, urban outlets in Malawi, including small shops, supermarkets, pharmacies, filling stations, or hotels. The respective processing enterprises directly distribute their produce according to orders received from these customers, and in selected cases established written contracts. Processors often reported the need to follow up with the retail outlets checking stock, since sales are season-dependent. Baobab juice, manufactured in 500 ml or 1 L plastic bottles, was predominantly stored in fridges at the respective retail outlets, yet some retailer also reported to store juice unrefrigerated, especially in cooler months. The more formalized baobab processing enterprises reported that their targeted final consumers typically belong to middle-class, health-conscious consumer segments.

Overall, and especially in the informal sector, business with baobab resources could be conducted with relatively little regulatory oversight. Stakeholders associated with the informal sector reported village chiefs and norms formed within the community to be of importance in various aspects concerning the handling of baobab fruit trees, with chiefs having to be informed before collection starts, although formally the forestry department is responsible for the protection of the forests, including baobab. City councils were the only authority mentioned within the informal sector concerning commercial baobab activities; however, this predominantly involved payment of market fees by people trading with baobab products. Other checks, e.g., on hygiene or food safety were only seldom conducted and awareness on quality standards was generally low to non-existent in the informal sector. Within the more formal baobab sector quality checks were more prevalent. Most importantly, the Malawi Bureau of Standards (MBS) was reported to check and certify baobab processing enterprises, whereas both processing facilities as well as manufactured products are inspected with regard to food safety and hygiene. Traceability, however, is not a requirement, thus processors do not need to keep track of their baobab sources. MBS certification is a prerequisite to be able to sell via supermarkets, although for smaller outlets this is often not a requirement, which are thus targeted by processing enterprises prior MBS certification. Although health claims on baobab products were found to be quite widespread in the formal sector, these were not regulated. Standards from the Poison and Medicine Board in Malawi were considered important if baobab is sold via pharmacies, with any herbal products having to be registered by the Pharmacy Board.

## Quality Characteristics of Baobab Products

### Perceived Quality Indicators

Amongst the most frequently handled baobab products, fruits and extracted pulp-on-seed, dryness was commonly considered the most important quality indicator across all interviewed value chain members handling these products (**Figures 3**, **4**, respectively; **Table 2**). To check for the desired dryness, fruits are commonly shaken—if the pulp can be heard inside the fruit is generally regarded as ripe. Other quality indicators, such as cracks in the fruit shell, fruit shape or color were more heavily disputed and only deemed important by 48.9, 59.6, or 57.8% of value chain members handling baobab fruit, respectively. A brownish color was the most commonly indicated desirable color for high-quality baobab fruit (38.5% of value chain actors handling fruit and deeming its color important), whereas all value chain actors handling fruit pulp and deeming its color as an important quality indicator agreed that the fruit pulp should ideally have a creamy-white color.

Depending on their position within the value chain and markets targeted, stakeholders perceived the importance of different quality characteristics differently (**Table 2**). Intact baobab shells and pulp cleanliness were of significantly higher importance for formal in contrast to informal value chain members, whereas sweet taste was more important for informal value chain members ($p < 0.05$; Pearson Chi-Square). Fruits with observed cracks were generally said to be discarded by the baobab collector association since they may be an entry point for water and/or insects; yet informal collectors or traders were less strict in this regard so that fruits with cracks can enter the supply chain. Particularly in the informal sector large fruits were preferred, primarily because better prices could be achieved. Commonly occurring contaminants in the baobab pulp such as fibers or pieces of the shell were often not considered to be a problem, especially in the informal sector, due to filtration during further processing activities.

### Mycotoxins and Mold Appearance

Mycotoxins were detected in two of the in total 77 analyzed product samples (**Table 3**), exceeding the EU threshold of 2 μg Aflatoxin B1/kg for dried fruits for direct consumption (EC., 2006). Both samples originated from Mangochi district, and were obtained from informal collectors typically selling their baobab to traders, one being a fruit sample and the other a pulp-on-seed sample. Over two thirds (73.5 %) of the interviewed value chain members handling baobab fruit pulp reported that mold can indeed be a problem, especially when baobab fruits are collected in the rainy season; but it can be avoided by further drying the pulp after cracking the fruit and grading.

### Vitamin C Content of Baobab Samples

Measured Vitamin C concentrations of baobab fruit, pulp, and powder samples showed high variances (**Figure 5**), with means standing at 127.7 ± 45.1, 125.0 ± 40.4, and 108.6 ± 35.3 mg/100 g, respectively, whereas no significant difference could be observed between these three groups (one-way ANOVA) or

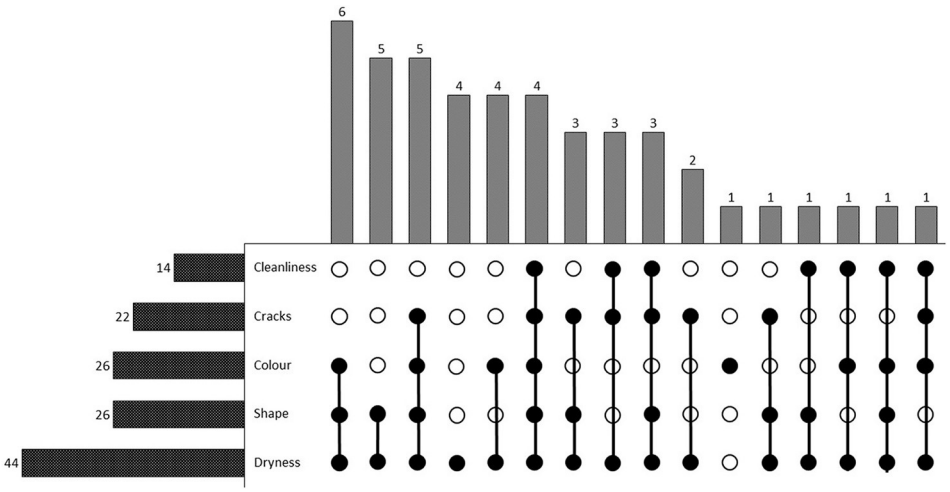


**FIGURE 3 |** Upset plot of important quality factors for baobab fruit indicated by respondents handling this product across the value chain ($n = 47$). The bar chart on the left indicates the overall frequency of the respective quality factor mentioned, whereas the bar chart above illustrates the frequency of quality factor combinations.

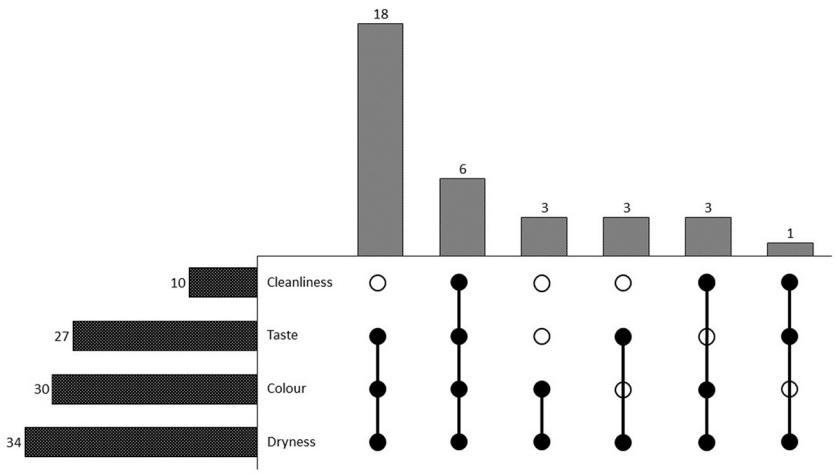


**FIGURE 4 |** Upset plot of important quality factors for baobab fruit pulp indicated by respondents handling this product across the value chain ($n = 34$). The bar chart on the left indicates the overall frequency of the respective quality factor mentioned, whereas the bar chart above illustrates the frequency of quality factor combinations.

between fruit and processed samples (independent samples *t*-test); with also only slight deviations between samples originating from informal or formal sources. Lowest Vitamin C values for both fruit and pulp were obtained from fruit harvested early in the season in February (17.3 and 51.3 mg/100 g, respectively), whereas the lowest value obtained for powder (36.2 mg/100 g) was observed on fruit harvested in April, all in Mangochi district and all supplied by traders. Powder obtained from formal retail outlets featured significantly lower Vitamin C levels (13.0 ± 3.3 mg/100 g) in contrast to samples from rural and urban informal markets ($p < 0.05$; independent samples *t*-test), whereas the particle size indicated that such powder probably equaled remaining stock from the defunct export market.

Considering harvesting periods, a trend toward lower Vitamin C values for fruit harvested early in the season was observed (**Figure 6**), yet the difference was not significant for all samples or the different product types, respectively (one-way ANOVA), whereas the samples from retail markets were excluded since the associated baobab was from previous year's harvest. April was the median harvesting month for all collected samples, although the collector association recommended harvest to take place in May and June to ensure the baobab fruit were sufficiently ripe and dry.

## DISCUSSION

The baobab sector in Malawi in recent years has rapidly transformed from subsistence use to widespread business opportunity, a development strongly influenced by involved entrepreneurs as well as developmental organizations rather than governmental support—confirming findings of te Velde et al.

**TABLE 2 |** Importance of different quality indicators for baobab fruit and pulp as judged by various value chain members handling these products ($n = 56$).

| | Fruit characteristics | | | | | Pulp characteristics | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Cracks in shell** | **Clean-liness** | **Color** | **Shape** | **Dryness** | **Clean-liness** | **Color** | **Dryness** | **Taste** |
| **Valid percentage [%] considering factor important** | **48.9** | **28.9** | **57.8** | **59.6** | **93.6** | **29.4** | **88.2** | **100.0** | **79.4** |
| **Informal VC members** | 39.5* | 22.2 | 59.5 | 65.8 | 92.1 | 21.4* | 92.9 | 100.0 | 89.3* |
| Informal collectors | 56.3 | 21.4 | 62.5 | 75.0 | 87.5 | n/a | n/a | n/a | n/a |
| Traders | 33.3 | 27.8 | 66.7 | 50.0 | 94.4 | 15.8 | 89.5 | 100.0 | 94.7 |
| Informal processors | 0.0 | 25.0 | 0.0 | 100.0 | 100.0 | 33.3 | 100.0 | 100.0 | 77.8 |
| **Formal VC members** | 88.9 | 55.6 | 50.0 | 33.3 | 100.0 | 66.7 | 66.7 | 100.0 | 33.3 |
| Formal collectors | 100.0 | 60.0 | 80.0 | 60.0 | 100.0 | n/a | n/a | n/a | n/a |
| Formal processors | 75.0 | 50.0 | 0.0 | 0.0 | 100.0 | 66.7 | 66.7 | 100.0 | 33.3 |

** significant results, $p < 0.05$.*

**TABLE 3 |** Characteristics of analyzed baobab samples containing mycotoxins.

| | **Contaminated fruit sample** | **Contaminated pulp sample** |
|---|---|---|
| **Sum aflatoxins [μg/kg]** | 3.2 | 9.1 |
| Aflatoxin B1 [μg/kg] | 3.2 | 5.3 |
| Aflatoxin B2 [μg/kg] | <0.2 | 1.8 |
| Aflatoxin G1 [μg/kg] | <0.2 | 1.1 |
| Aflatoxin G2 [μg/kg] | <0.2 | 0.9 |
| **Vitamin C content (mg/100 g)** | 153 | 158 |
| **Estimated month of fruit harvesting** | July | April |
| **Time between fruit harvest and pulp extraction** | 3 months | 3 months |
| **Color of fruit pulp** (RHS Color Chart) | Pale yellow (18C) | Pale yellow (158B) |
| **Observable mold on pulp** | Not visually observable | Mold observable, medium intensity |

(2006) or Grivins and Tisenkopfs (2018) who highlight the importance of entrepreneurship in shaping new NTFP value chains with policy support often lacking. While from a historic perspective the initial focus in Malawi has been on establishing formal supply chains, this has also fueled developments in the informal sector. An increasing number of microenterprises have started to process and trade baobab resources for an additional income opportunity via informal pathways, besides a small number of enterprises targeting higher-value market segments. These results confirm findings of other baobab value chain studies in Malawi in terms of actors involved in the chain (Amosi, 2018), as well as the differentiation between informal and higher-value markets and an associated divide of consumer segments (Darr et al., 2020). As such, Malawi may well be an exception and forerunner in the region. For instance in Kenya baobab can still be considered underutilized with a relatively low importance for local consumption, with only one processed product available on informal markets (Jäckering et al., 2019). In South Africa, domestic, local baobab use has lost its importance, a gap which has been filled by a sophisticated export market (Welford et al., 2015). The situation in Malawi, therefore, seems more comparable to Western African countries, where domestic demand for baobab is higher and fruits are being processed on a local and semi-industrial level into a variety of different products, including juice, syrup, jam or instant juice powder (Caluwé, 2011).

With the rapid increase in demand for a formerly solely traditionally used resource, handling practices e.g., considering harvest, storage, or processing have changed as well. Similarly to the situation in Western African countries (Caluwé, 2011), highly variable post-harvest practices and little standardization was observed in Malawi, which may explain the unreliable quality of baobab products available on the market. For instance, with harvesting periods peaking in April yet sales dominating in the hot months between September and December, baobab is stored for long time periods in Malawi with differing storage and post-handling practices. Storage duration and conditions can, however, particularly impact the Vitamin C levels baobab products are renowned for, leading to potentially substantial reductions (Chadare, 2010; Tembo, 2016). Together with the fact that Vitamin C content in baobab fruits can also strongly vary naturally, for instance depending on genetics or soil type (Assogbadjo et al., 2012), this may explain the high variation of Vitamin C levels observed in analyzed product samples. Such effects may hamper the often advocated positive effects on food and nutrition security due to consumption of baobab products. Negative implications on product quality have also been reported for other NTFPs, especially if harvested too early or handled inappropriately after harvest (Kadzere et al., 2006, 2007). This can, particularly, enhance the risk of mycotoxin contamination, as also observed in two cases of analyzed samples in Malawi. Mycotoxin contamination can occur at all stages during the production process, facilitated by factors such as high temperature, moisture content and water activity, and can lead

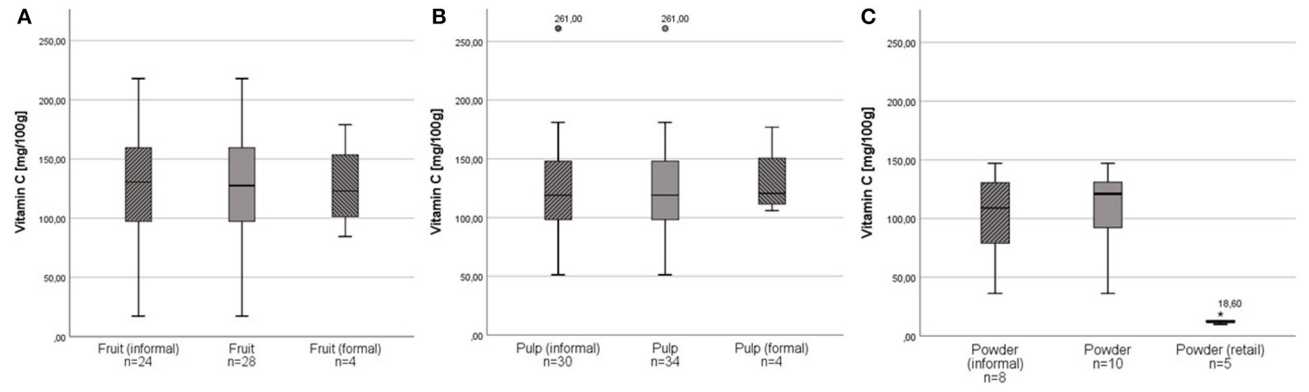


**FIGURE 5 |** Boxplots of Vitamin C content of baobab fruit **(A)**, pulp **(B)**, and powder **(C)** samples.

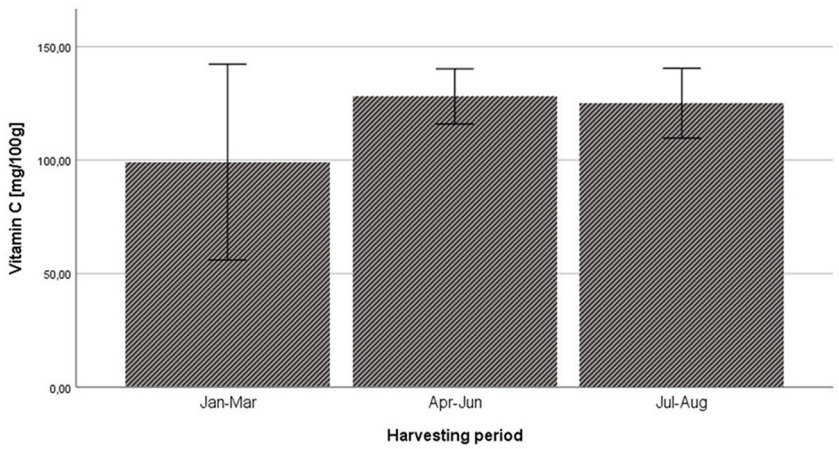


**FIGURE 6 |** Vitamin C content by fruit harvesting period (error bars: 95% CI).

to serious health as well as economic implications (Darwish et al., 2014). For instance, producers of Brazil nut harvested from the wild lost access to European markets due to failures to meet the desired quality standards (Coslovsky, 2014), similarly to the demise of the baobab exporting sector in Malawi. Although most baobab value chain members commonly highlighted the importance of dryness to ensure high product quality and reduce the risk of microbiological contamination, further alignment on perceived quality characteristics and awareness on quality aspects seem necessary, although, in times of crisis and need for cash or food, the risk of quality being a point of neglect still remains a great concern. For instance, case studies on marula (*Sclerocarya birrea*) have demonstrated that small-scale harvesters have excellent knowledge on fruit ripening and quality control parameters and can identify optimum ripeness levels based on the fruits color (Suárez et al., 2012). This may indicate that knowledge and awareness on quality aspects alone will not be sufficient to tackle quality challenges.

Overall, the case study of increased baobab commercialization in Malawi highlights both aspects relating to increasing NTFP use as well as issues concerning smallholder agriculture reaching high-value markets. The increasing domestic demand and acceptance for wild forest products led to changes in the market structure and supply chain organization, including chain elongation, new actors, particularly traders and processors, entering the scene, or traders commonly visiting and picking up resources directly from collectors early in the season. Similar effects have also been demonstrated for other NTFPs shifting from subsistence use, e.g., wild blueberry commercialization in Latvia (Grivins and Tisenkopfs, 2018) or palm fiber handicrafts in Brazil (Virapongse et al., 2014). Phumee and Pagdee (2021) highlighted changes in NTFP selling tactics and an increased role of trading, while local livelihoods changed from subsistence to market-driven. Such effects can at least partially also be explained by the rapidly changing agri-food sector in sub-Sahara Africa and underlying transformation drivers such as income growth, policy liberalization, privatization, and infrastructure investment. These facilitate increased urbanization and dietary changes, which in turn impacts food supply chains, leading to elongation of the chains to be able to satisfy the demand of cities, especially with

regard to segments beyond the farm level. Furthermore, the role of food purchases in urban areas gains importance, moving away from subsistence livelihood strategies (Reardon et al., 2019). Such trends could also be observed in the newly formed baobab value chains in Malawi.

Associated trends within the broader transformation of the agri-food sector in Africa, such as increasing demand for high quality food products, especially processed products, or an increasing role of supermarkets or standards were to a certain extent also present in the study. Baobab is nowadays available in formal retail outlets in Malawi, whereas different quality standards need to be observed by the supplying processing facility to enter these markets. Yet within the baobab supply chain it is typically only the more formally operating processing facilities being aware of and having to fulfill these requirements. With most processors obtaining their raw material via traders and standards not including aspects such as traceability, the risk of low-quality baobab entering formal retail outlets remains. These outcomes are perhaps associated with the observed changes in supply chain organization, whereas traditional systems to ensure quality based on trust and personal relationships are not yet fully substituted by formal, anonymous systems to comply with minimum quality criteria. Similarly, customary rules at community level via directives from village chiefs were shown to be the main criteria to ensure marula fruit harvesting to take place at the correct time and fashion (Tapiwa, 2019), yet such rules may be eroded with increasing focus on commercialization activities.

Achieving high food quality is yet a major issue for many African countries with food processing enterprises often lacking sufficient food safety and hygiene schemes such as HACCP or ISO22000, limited coordination between supply chain members, lack of sector-specific guidelines or limited legislative capacities and involvement of food safety authorities, amongst other issues (Ruben et al., 2007). While quality standards have the potential to reduce transaction costs by reducing asymmetric information and, consequently, make supply chains and markets more efficient (Bijman and Bitzer, 2016), the importance of assistance, supervision and control programs to achieve the needed quality has been highlighted as a success factor for smallholders accessing and benefitting from high value markets (Henson et al., 2005; Minten et al., 2009). With adequate regulations e.g., on health claims or traceability lacking in Malawi and the main actor overseeing food safety standards regarded as underfunded and underequipped, there is, therefore, a dire need to strengthen the institutional framework and enabling environment to foster production of high-quality products. In this connection, emphasis should also be put on the substantial informal sector where hardly any regulatory oversight concerning quality control was observed. Smallholder producers can make a considerable contribution to the production of high-value food commodities, especially considering nutritious NTFP products such as baobab, yet policy support and awareness for quality considerations needs to be strengthened. This should also entail enabling regulatory frameworks concerning the resource base fostering pro-poor and sustainable harvesting practices, which is currently dominated mainly by customary rules at community-level. The often high complexity of NTFP regulations and lacking, inadequate, or bureaucratic enforcement of these have been shown to impede the creation of an enabling business environment for sustainable NTFP commercialization (Tieguhong et al., 2015; Ingram et al., 2017).

## CONCLUSION

Forests and trees represent an important food repository and can make notable contributions to achieve food security, yet with interest rising in forest food resources pathways have to be found on how to best integrate such resources into prevailing agri-food systems. Whilst the risk of overexploitation of NTFPs due to increasing demand has often been acknowledged, more focus needs to be put on quality aspects when NTFPs transition from subsistence use to retail commodity. More research is needed with regard to appropriate harvesting periods, handling practices and storage conditions during the entire production to consumption chain, including the development of adequate quality control procedures. Research on consumer perceptions concerning product quality may also be a useful tool to aid the transition and inform value chain members on which quality aspects to particularly focus on. Although basic knowledge on quality indications may be present amongst value chain members, further awareness and capacity building efforts along these lines may be helpful. Furthermore, improved information flows and relationships amongst value chain actors as well as supporting regulatory frameworks, considering both the NTFP resource base as well as quality management strategies, are needed to reduce the risk of low-quality materials entering food supply chains. With NTFPs transitioning from traditional use, where customary rules concerning NTFP management dominate, to commercialized resource, there is a need to establish suitable formal NTFP management strategies and policies to ensure the long-term sustainability of the resource. Furthermore, regulatory frameworks concerning quality standards need to be strengthened and enforced in both formal and informal segments, which are not likely to evolve by market forces such as consumer demand alone, but require active regulatory intervention.

## 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 Malawi National Commission for Science and Technology. The patients/participants provided their written informed consent to participate in this study.

## AUTHOR CONTRIBUTIONS

KM and DD contributed to the overall conception and design of the study. KM carried out the investigation, subsequent analysis,

and wrote the first draft of the manuscript. DD contributed to manuscript revision and editing. All authors read and approved the submitted version.

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