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Enabling Food Safety Entrepreneurship: Exploratory Case Studies From Nepal, Senegal, and Ethiopia

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Today, formal and informal enterprises are increasingly contributing to the safety and nutritional ramifications of their food business activities. Enabling entrepreneurship in a sustainable manner means making profits, striving to prevent ingress of harmful substances, and increasing the efficiency of using local natural resources and thus mitigating food hazardous footprints. Using examples from Nepal, Senegal and Ethiopia, this review provides information on microbial and chemical contamination and food adulteration that lead to having unsafe food in the market and on factors that are limiting growing food businesses. Four examples for how to accelerate food safety entrepreneurship are presented that include safely diversifying markets with animal sourced foods, sustainably using neglected and underutilized animal sources, expanding, and integrating innovative technologies with traditional practice and using digital technology to improving monitoring and safety along the food supply chain.

Keywords: food, entrepreneurship, supply chain, safety, nutrition, market, system

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INTRODUCTION

Access to safe and nutritious food is one of the most complex social and economic problems that has transparent frontiers and exists practically everywhere on the world map. The recent emergence of a "New Food Equation," marked by food price hikes, dwindling natural resources, land grabbing activities, social unrest, the effects of climate change, and recent pandemic impact of COVID-19 is bringing onto the global food security and safety agenda a range of often interrelated sustainability concerns (Sonnino, 2016; Apostolopoulos et al., 2021). All these issues form a challenging environment in which food businesses operate but at the same time trigger the positive changes that can strengthen food safety systems. In particular, COVID-19 provided a boost to short supply chains in the agri-food sector and agri-food enterprises and those with new technologies and digital aspects at their core were privileged in competition. Agri-food enterprises relying on transportation for their inputs were limited in operations due to travel restrictions. Simultaneously, there was a forced change from fresh to dried agri-food products e.g., dried seafood (sardines, prawns), meat (beef jerky, goat meat), beans, lentils, and peas, fruits (bananas, mangos, pineapple), and vegetables (tomato, onion, okra) affecting agri-food entrepreneurial activities (Bene, 2020; Apostolopoulos et al., 2021; Belton et al., 2021; Nordhagen et al., 2021).

Following these conditions in prerequisites, for low- and middle-income countries (LMICs), the most promising trend in future foods depends to a large extent on food businesses awareness. Hence, the ability to expand the production of local foods and the need to employ indigenous and new technologies for food processing to produce safe, nutritious, and healthy products. Identifying and implementing technologies that reduce greenhouse gases and use of green technologies for transporting, processing and packaging that preserve the safety, quality, and nutritional value of food products provide an important avenue for building local and national economies. Among these novel technologies are the smart packaging systems based on natural food colorants for the monitoring of food quality and safety, digitalization of basic logistic processes realized through Internet-based solutions, light-emitting diode technology, smart moisture detection, and various other innovations to multiple health and environmental benefits along food supply chain (Alizadeh-Sani et al., 2020; Prasad et al., 2020; Chitrakar et al., 2021; Forcina and Falcone, 2021).

The rationale of this review is to understand the challenges food entrepreneurship is facing related to food safety and what kind of targeted interventions would be relevant to a particular country context. Diversity within country contexts will provide an opportunity to observe how ongoing or future food safety actions succeed or fail under a variety of circumstances.

By screening the existing drawbacks in food systems through the prospects of what food businesses can contribute in a given country context, stakeholders will be more capable in designing and implementing actionable and incentive-based recommendations for better food and nutrition safety practices. Effective food safety interventions should ensure that the size of the action is adjusted to the size of the problem, i.e., the level of effort is proportional to the significance of the expected impact. A number of recent reviews have found that diverse agricultural interventions have increased food production, but did not necessarily improve nutrition and "post-farm gate" methods that increase the availability, affordability, acceptability and consumption of nutritious foods also needed to support food safety for small formal and informal enterprises that often cannot comply with legislated criteria (Maestre et al., 2017).

Studies from Nepal, Senegal and Ethiopia were reviewed to identify key food safety issues and barriers to improving food safety practices and nutritional status of foods. These countries were selected because they have demonstrated potential to reshape their food safety systems that contribute to the sustainable development of the agri-food sector economy. Some of the significant signals that food safety and nutrition concepts are beginning to shape expectations and regulatory requirements in these countries include:

- Increased contributions to the large body of peer-reviewed materials and gray literature actualize and explore the problems of food safety and nutritional quality protection at the level of small- and medium businesses (Noort et al., 2016; Morse et al., 2018; Joardder and Masud, 2019; Nyarugwe et al., 2020).
- National governments of Nepal, Senegal and Ethiopia are exploring policy mechanisms to restore, maintain and evolve services around food safety (Grace, 2015; GFSP, 2018; Birke and Zawide, 2019; Uprety and Shivakoti, 2019; Forsido et al., 2020; Osti, 2020).
- A growing number of food entrepreneurs are ready to apply food safety best practices as pilot tests with a focus on business profits (Kussaga et al., 2014; Dongol et al., 2017; Dizon et al., 2019; Getachew and Christian, 2019; Ghimire and Koirala, 2019; Thapa et al., 2019; Bene, 2020).
- Trendsetting financial institutions have put into place requirements to consider food safety standards within financial due diligence processes (Van der Heijden et al., 1999; Kirezieva and Luning, 2017; Steier and Patel, 2017; FAO et al., 2020).

The following section illustrates existing and emerging drivers for food safety and include specific and sensitive insights that promote and inhibit growing sustainable food businesses.

UNSAFE FOOD AS PUBLIC HEALTH RISK

Historically dietary patterns in Nepal, Senegal, and Ethiopia are a mixture of plant and animal-sourced foods (ASFs) that are often minimally processed. As the population is increasing, especially with migration to urban areas, there is a modern trend to continuously expand food businesses to meet this shift in the size and location of the population. World projections modeled on the last 5 years of growth in urbanization, per capita income, and rates of income inequality anticipate that by 2040, 72% of all food will be processed to some degree, up from 58% today. Rural processed food consumption will grow from 43 to 50% and urban processed food consumption from 91 to 95% (IFTF, 2018). The distance between production and consumption spots are stretching and a number of developments which include changes in pre- and post-harvest practices are contributing to increased threats of biological, chemical and physical hazards on food safety.

Microbial contamination, chemical contamination, and food fraud are commonly reported public health risks related to food safety along the value chain in Nepal, Senegal, and Ethiopia. These challenges include, but not are limited to.

Microbial Contamination of Food

Failure to apply food safety strategies in every stage of the food supply chain, for example, bad feeding and watering practices, poor animal health, unhygienic production system, underdeveloped practice of packaging and labeling, poor infrastructure, informal market channels, poor marketing practices, and poor hygiene and sanitation lead to microbial contamination of foods. Moreover, fraudulent food processing practices such as adulteration, and selling of spoiled or expired foods are also causing microbial contamination (Dongol et al., 2017; Doutoum et al., 2018; Dhungel et al., 2019; Behera et al., 2020; Owusu-Kwarteng et al., 2020; Teferi, 2020; Teixeira et al., 2020). Numerous pathogenic microorganisms have been found in different food items along the value chain. The

following disease-causing bacteria were commonly reported in the target countries: *Salmonella* spp., *Escherichia coli, Klebsiella* spp., *Shigella* spp., *Citrobacter* spp., *Pseudomonas* spp., *Vibrio* spp., *Campylobacter* spp., *Listeria* spp., *Cryptosporidium, L. monocytogenes, Brucella* spp., *Coxiella burnetii, Proteus* spp., *Staphylococcus* spp., and *Bacillus cereus* (Hempen et al., 2004; Dahal et al., 2010; Mersha et al., 2010; Kirk et al., 2014; Adugna et al., 2015; Abera et al., 2016; Atnafie et al., 2017; Markos et al., 2017; Mengistu et al., 2017; Bantawa et al., 2018; Dhungel et al., 2019; Kassahun and Wongiel, 2019; Keba et al., 2020; Kumar et al., 2020; Osti, 2020). The available sources indicate a trend toward increasing resistance rates among pathogens such as *Escherichia coli, Shigella* spp., *Salmonella* spp., and *Staphylococcus aureus* to commonly prescribed antibiotics, including ampicillin, amoxicillin, penicillin, tetracycline, and trimethoprim/sulfamethoxazole (Tesfaw et al., 2013; Dulo et al., 2015; Garedew et al., 2015; Ejo et al., 2016; Assefa and Bihon, 2018).

Chemical Contamination of Food

Food contamination with hazardous chemicals is one of the major public health concerns associated with the phases of food production, processing, packaging, transportation, and storage. Mycotoxins pose significant food safety challenges in the studied countries. In Ethiopia, aflatoxins, ochratoxin A (OTA), deoxynivalenol (DON), zearalenone (ZEN) and fumonisins (FUM) are considered to be widespread in major dietary and export-oriented crops (Ayelign and De Saeger, 2020). Getachew et al. (2018) reported the occurrence of 127 mycotoxins in maize grains collected from the major maize producing districts in Ethiopia. In the area of Southern Senegal a recent study found that 17 of 84 maize samples (20%) taken randomly from post-harvest cobs or shelled corn contained positive levels of aflatoxin (Bauchet et al., 2020). Studies of prevalence of aflatoxin contamination in Nepalese maize production have shown that the incidence in maize is high and average prevalence is about 50% (Pokhrel, 2016).

Among the hazardous chemicals commonly reported for grains, cereals, horticultural crops (mainly eggplants, tomatoes, chilis, lettuce, cabbage), fruits (banana), chicken eggs, pelagic fish, shrimps, dairy products are: heavy metals (like cadmium, zinc, iron, mercury, lead), pesticide residuals (like dicofol, chlorpyrifos, dimethoate, and λ-cyhalothrin), persistent organic pollutants [like lindane, hexachlorobenzene (HCB), cyclodienes (heptachlor and trans-nonachlor), DDT, dioxins, polychlorinated biphenyl (PCB)], organic compounds (like formalin, urea), and other chemical compounds (like bicarbonate, sodium hydroxide, sodium carbonate). In most cases, the concentration of chemicals has been found to exceed the tolerable limit for consumable food items (FAO, 2014; Thompson et al., 2017; Guy Bertrand, 2019). As an empiric example, a study of mercury, lead and cadmium contamination in fishery products from Senegal has detected mercury in 71% of the samples, cadmium in 60%, and lead in 58% of the samples. The greatest mercury contamination value (0.55 ppm) was found in cuttlefish during the 9-year study (Diouf et al., 2019). An investigation of pesticide residues in food indicated a 3-fold higher DDT residue concentration above the acceptable daily intake set by the WHO in human mothers' and cows' milk samples. On top of the risk of pesticide residues in dairy products, other studies in Ethiopia also showed residues of organochlorine pesticides in cattle carcasses and honey samples (Negatu et al., 2021). In Nepal, due to over use and unsafe handling, the issue of pesticide use in agriculture farming is becoming a growing public health concern. Pesticide application is concentrated in relatively few provinces and is increasing by about 20% per year. Of the total pesticides imported in the country, more than 90% are used in vegetable farming (Kafle et al., 2021).

Food Authenticity Issue

The large number of food fraud incidents have impacted almost every stage of the food chain, and is identified as growing trend. Food fraud involves intentional or unintentional addition of useless, harmful, unnecessary chemical, physical, and biological agents to food which decreases the quality of food. It also includes removal of genuine components and processing foods in unhygienic way. The impacts of such incidents are far reaching, affecting not only consumers' trust to agri-food business and the reputation of the food supply chain but also present possible public health repercussions if a food fraud incident involves the addition of harmful substances or allergens. Chemicals [like metanil yellow, rhodamine, sudan red, calcium carbide, formalin, bicarbonate, sodium hydroxide (caustic soda), sodium carbonate, neutralizers, detergents]; items which are not the genuine component of foods (like starch, flour, water in milk, cow's fat and intestine in ghee, poisonous plant derivative); poor-quality products; and physical or inert agents (like clay, brick powder) are the commonest adulterants added mostly to dairy products, cereals, legumes, rice grains, edible oil, ghee, flour, and pepper (Sapkota and Phuyal, 2016; Gemechu et al., 2020; Thapa et al., 2020).

The case from Nepal illustrates that most of the times, the adulteration is intentional for raising profit, but it can be due to the lack of proper detecting technology and confusion regarding appropriate drug administration practices (Bhandari, 2020). Market inspection carried out in 2018 by the Department of Food Technology and Quality Control found that packaged milk sold in Kathmandu was adulterated with chemical contaminants such as washing soda and detergent chemicals. Harmful chemicals like bicarbonate, sodium hydroxide (caustic soda) and sodium carbonate were found in the 42 samples of packaged milk collected from 25 milk processing plants, which the firms had been using as neutralizer during storage. The deliberate mixing of milk with water, flour with gypsum, butter with banana, edible oil with poisonous plant derivative, and pepper with clay have been some of the reported cases in recent years in Ethiopia (Birke and Zawide, 2019).

Ways to ensure the quality and safety of food products is to guide priorities and to work with local food businesses to design actions to transform incentive-based business-to-business relationships within formal food and informal food networks.

The following actions for rebuilding the entrepreneurial partnership with agri-food business are consistent and applicable, albeit modified as needed for each explored country.

- Providing technical input on regulations and oversight for the implementation of food safety practices that improve local standards and meet export requirements.
- Provision of economic assistance to develop appropriate financial incentives. Governments and other financial institutions need to implement incentives for businesses to increase food safety practices. It is recognized that incentives may be more difficult for the informal and small businesses.
- Development and evaluation of food safety education materials and their impacts. A frequent finding is the need to educate all stakeholders. These stakeholders include consumers who need to link food safety with health; food producers who need to understand how food safety practices improve their return on investment; and policy makers who need to understand the intimate relationship between food safety, economic development, and public health.
- Development and dissemination of workshops and courses. Trainings need to focus on technical issues for implementing food safety practices and be directed to key personnel working in food businesses. Additionally, the trainings need to address the cost effectiveness of food safety practices.
- Provision of technical assistance and setting up collaborations. In order to have a successful scaling up of food safety practices, it is recognized that there needs to be collaboration among all stakeholders to implement and maintain these practices.

The success of such actions relies heavily on the understanding of food products, value chain functioning, consumer awareness of the value of nutrition and food safety, and expectations of agribusiness main actors.

FACTORS LIMITING GROWING FOOD BUSINESSES

Nepal, Senegal and Ethiopia are diverse countries in terms of geography, ethnicity and socioeconomic conditions. The market for food businesses in all three countries is strong due to an increase in population, an increase in demand for ASFs, a limited number of food-oriented businesses, and a large dependency on imported foods. Increasing local food businesses can enhance the income of small and medium size businesses and stimulate a slowly growing economy (Lake et al., 2015; Kwil et al., 2020). Small and medium size agri-food businesses now experience significant challenges from the local level all the way up to being engaged with international trade (Sautet, 2013; Deller et al., 2017). Unfortunately, food systems safety are decades behind in adopting technologies, standards, and business management tools due to various on-going weaknesses of the local market systems.

There are significant constraints to providing safe food with over 80% of food sold in informal markets that have restricted access to clean water, consistent power, and sanitary and waste disposal, and even social norms and beliefs (Haileselassie et al., 2020). Inroads to increasing food safety measures for food businesses in the informal sector especially need to address how they increase short and long-term revenue to balance the required risk adverse behaviors from this sector. At the same time, the informal market participants can play a leading role in driving positive change through coordinated and co-shared food safety and quality responsibilities. For example, many people engaged in informal markets are highly knowledgeable about the indigenous methods of shelf-stable food safety which can be optimized and modernized to meet current market demands.

Meat and Dairy

Meat and dairy production are potential drivers of economic growth in Nepal. While several private companies operate in the dairy sector the lack of road access to urban areas has discouraged private investment in areas where the bulk of milk and meat are produced, preventing most producers from linking into value chains. Lack of access to affordable financing, credit, and information services have made it difficult for the private sector to establish and operate milking centers, processing plants, and other commercial operations (Sharma, 2017).

An example of a food safety specific influence relates to the production of safe and hygienic milk. This is especially the case for the dairy sector of Nepal (Kumar et al., 2017). In a survey of raw milk in Nepal, it was found that out of the 129 samples, 25% were positive for *E. coli,* 37.2% for *Salmonella* spp., 5.4% for *Shigella* spp., 7.7% for *Klebsiella* sp., 18.6% for *Citrobacter* spp., and 1.6% for *Pseudomonas* spp.. Air, feed, grass, soil, feces, and milking equipment were considered the primary sources. For a country with one of the worst child nutrition statistics in the world, safe, and hygienic milk production is critical (Dhungel et al., 2019).

The informal milk sector, which accounts for three quarters of Nepalese production, has a similar issue since it is sourced primarily from small and subsistence-level farmers. They produce primarily for household consumption and sell the excess into local markets for consumption as raw milk or for artisanal processing. Milk transacted through these channels is neither pasteurized nor labeled, and usually does not follow most of the good agricultural practices (GAP). In the small segment of branded dairy products, both pasteurization and labeling exist. Without pasteurization and adoption of GAP, the milk from the informal sector tends to be prone to adulterants such as water, benzoic and salicylic acid, detergents, urea, formalin, sugar, carbonates, and ammonium sulfate, partly due to pricing by fat content at the first point of sale (Thapa et al., 2020).

On average, a dairy farmer in Nepal has to incur an additional expenditure of Rs 2 (0.017 USD) per liter of milk production in order to follow food safety measures (FSM). Farmers are not very enthusiastic about fully complying with FSM since it involves incremental costs and the markets in Nepal often do not reward food safety. There are certain ways to address food business actors' initiatives around safety through public promotion (newspapers, websites, social media, banners); food safety recognition awards; favorable offers for testing, inspections and certification; consulting in standards design; customized business solutions, etc. In order to reach diverse audiences in terms of food safety recognition, digital communications should complement, not replace, traditional methods.

The results of a food safety consciousness study among the Nepalese smallholder dairy farmers revealed that an increase

in the food safety consciousness level by 1% increased the weekly milk expenditure, milk price paid, and weekly milk purchased by 1.37, 0.66, and 1.27%, respectively. Furthermore, an increase in food safety consciousness by 1% was associated with a 37% higher probability of selecting a modern milk outlet (Thapa et al., 2019).

The food entrepreneurs—mainly processors, traders, and retailers—lack the knowledge, adequate incentives, and understanding of how to prevent risks or mitigate impacts of food safety hazards. By incorporating food safety risk mitigation into their business operations, entrepreneurs can improve their competitiveness and overcome barriers of mistrust and negative perceptions about costs of actions to provide safer and more nutritious food to consumers. They also lack skills of setting and implementing certain food safety standards and procedures in a consistent and repeated manner for post-harvest loss minimization.

Eggs

Many technologies for reducing losses exist, but they are barely utilized and some of them have not yet been introduced in many LMICs. Examples include hermetic bags, heavy molded-plastic containers, and mobile processing units. These innovations have a small unit cost and are suited to individual use.

A study from Nepal by Martin Metzger states that the sustainability of small production Nepalese farmers is very important to egg production and consumption. For eggs to be transported without damage, egg trays or cartons are crucial, but for farmers to have access to egg cartons or trays, they need to be economical, available, and useable. Plastic egg trays cost more and because Nepal is a cost sensitive market, plastic egg trays are out of the price range. Therefore, pulp egg cartons are the safest, easiest to produce and most beneficial for Nepal.

Providing Nepalese farmers with egg cartons and trays can be achieved through two methods. The first method involves importing and distributing egg cartons or trays throughout Nepal. The more distribution centers that are set up, the shorter distance farmers would have to travel to get egg cartons and trays. The distribution center could become a new business for Nepalese entrepreneurs who want to help farmers by facilitating distribution of the egg cartons and trays. Multiple distribution centers could be independently owned and operated but linked to one larger distribution center that facilitates the importation of mass quantities of egg cartons and trays. By having one large distribution center supplying the smaller ones, it prevents price fixing and creates an equal price throughout Nepal. The second option is manufacturing egg cartons and trays in Nepal in either large or small-scale operations. There are many benefits to manufacturing egg cartons and trays in Nepal, but the main one is the direct boost to the local economy. Egg carton and tray production can be either a large or small-scale operation. There are no manual tools for making egg cartons or trays, so regardless of the system, it has to be in an industrial setting. With the goal of benefiting small production Nepalese farmers, the advantages and disadvantages of each solution have to be studied precisely.

Fish

Creating an infrastructure to expand food safety practices, in the aquaculture and fisheries in Senegal for fish destined for local markets, need to address the unsanitary handling of fish due to a lack of adequate cooling which is the greatest food safety issues for this sector (Doumbouya et al., 2017; Lancker et al., 2019). Additionally, much of the production and harvest is undertaken by small-scale farmers and fishers who lack adequate resources to adopt safer food practices. Additionally, local markets lack the economic and regulatory drivers of food safety that export markets demand. In Senegal, like in many emerging economics, there is a lack of adequate processing infrastructure or electricity in landing sites and this contributes to significant food safety risks, post-harvest loss, and limits economic performance (Diop et al., 2019). Fish often lack icing or refrigeration from processing to final point-of-sale; and large quantities are processed using traditional techniques that can introduce harmful chemicals into products, such as polycyclic aromatic hydrocarbons (FES, 2000, 2021; Vergis et al., 2021). In Senegal, recent studies of the quality and safety issues in the minced sardinella filets production has shown that the sanitary conditions of the fish handling and preparation environment are poor: the floor is often sandy, dirty, or of damaged cement or tiles; lack of drainage facilities for wastewater; irregular and inadequate removal of solid wastes, absence of toilet facilities and potable water at some places. The operators were aware of these conditions and at least two thirds among them stated that they would have attracted many more customers and boosted their business if hygiene within their places was improved. Antidotally, the respondents recognized that the longest queue of customers in the market was for the kiosk owned by three women who applied comparatively better hygienic working practices, though their service was more expensive (Diei-Ouadi, 2005).

Small producers are unable to respond to the market-pull from country-level commercial producers, processors and traders. They lack assets, knowledge and understanding of values and culture of food safety management, organizational skills to consistently produce and process the nutrient rich food products in variety, quality, and volumes needed for local markets. Gross margin analysis on few dairy products sold by the private dairies in far-western Terai districts of Nepal revealed that selling curd, paneer, Khoa, and ice cream was two times, five times, and twenty times profitable, respectively than the selling standard milk (Bhandari, 2018). Moreover, there are underutilized indigenous food products in the studied countries that can be commercially produced and compliment food and nutrition security efforts. As an example, according to Aragaw et al. (2021) Ethiopia hosting hundreds of edible plants can fulfill nutritional demands of local people. Among the explored underutilized edible plant species in coffee agroforestry systems of Yayu, southwestern Ethiopia leafy vegetables, such as *Amaranthus graecizans*, *Portulaca oleracea,* and *Solanum nigrum*, have proved to be good sources of protein and minerals (Ca, Fe, and Zn). Other species were reported to be good sources of pro-vitamin A (*Rubus apetalus*) and vitamin C (*Syzygium guineense*), while at the same time contain relatively low amounts of antinutritional factors. It was found that the

nutritional values of the analyzed plants is comparable and sometimes higher than the ones of conventionally cultivated crops, e.g., *Portulaca oleracea* provides more dietary Iron than maize (Aragaw et al., 2021). The commercial potential of these plants lies in flourishing demand for superfoods with the nutritional, antioxidant, and antibacterial properties.

The study highlighted the fact that national governments are developing policy mechanism to restore, maintain and evolve services around food safety. In response to these efforts and due to local demands, most businesses practice food safety procedures but not always. Among the major on-going food safety challenges in Nepal, Senegal and Ethiopia are domination of informal markets that lack an enabling environment for implementing food safety practices, with significant constraints including restricted access to clean tap water, constant power supply, and waste disposal. Processors, traders, and retailers lack the knowledge of how to prevent risks or mitigate impacts of the food safety hazards. Further, they lack adequate incentives and a clear understanding of how modifying business operations can improve their competitiveness. This knowledge and understanding can help overcome barriers of mistrust and negative perceptions about costs of actions to provide safer and more nutritious food to consumers.

Growing agri-food business actors also lack skills of setting and implementing certain food safety standards and procedures in a consistent and repeated manner. More importantly, the surveillance systems and enforcement of regulations need to be strengthened and be more consistent to improve food safety. The most important motivational factor for food businesses to adopt safe food practices is improved product quality and factors related to consumers such as certification visible to the consumers and improved consumer preferences along with improved profits.

Overcoming the above-mentioned limitations in the emerging economies inherently necessitates active entrepreneurs' involvement into food safety procurement.

INSIGHTS TO FOOD SAFETY ENTREPRENEURSHIP ACCELERATION

The food industry provides various entrepreneurial opportunities along the food value chain and US and European agriculture investment activity has been on the rise in the area of converting and packaging in particular, followed by agriculture production and shipping and selling (Kuckertz et al., 2019). Hence, food safety interventions and business innovations are more likely to attract investors if they encompass initiatives along these steps in the value chain.

Examples of entrepreneurial opportunities for health and safe food market expansion include: superfood bites from indigenous nutrients-dense plant species, artificial intelligence and chemical sensing for food grading and sampling, antimicrobial food packaging based on local bio-based materials, processed premium exotic animal meat, and ancestral food promotion.

Four segmented pathways were identified for entrepreneurship acceleration based on safety, nutrition, technology, and food that are present in these countries. The first pathway is to diversify markets with ASF. Second, food producers can improve their utilization of neglected and underutilized ASF. Third, growing food businesses require applying and integrating innovative technologies with locally scaled food practices. The fourth potential pathway is to introduce digital geotechnologies for on-going management that support growing food businesses.

Diversify Markets With ASF

From a health and environmental sustainability perspective, including ASFs can be an important source of nutrients that include its positive effects on plant diversity and on local economies. Expanding ASF requires producing feed, creating sustainable, and ethical practices for raising animals, and creating and marketing ASF products that utilize environmentally sound principles and address the double-burden of malnutrition that exists in LMICs.

For the countries studied, one of the most promising trends in future foods depends as much on entrepreneurs' awareness as it does on the ability to expand the production of local foods and the need to employ traditional and new technologies for ASF processing to produce sustainable, safe, nutritious, and healthy products (WorldBank, 1998; Godfray et al., 2010; Hodges et al., 2010; Asogwa et al., 2017; Dizon et al., 2019; Baldwin and Evans, 2020; Kuyu and Bereka, 2020). Identifying and implementing practices that reduce greenhouse gases and use green technologies for transporting, processing and packaging that preserve the safety, quality, and the nutritional value of food products provide an important avenue for building local and national economies. According to Kuyu and Bereka (2020) some of these practices include the use of botanical plants in the storage for post-harvest pest management, treatment the storage structure with hot pepper, tobacco dust, wood ash, sand, sawdust, neem seed powder, etc. (Kuyu and Bereka, 2020). Among the specific botanical plants, which have been documented as grain protectant in the storage, are the following: basil powder as insecticide against maize weevil (Mwangangi and Mutisya, 2013), *Eucalyptus tereticornis, Tagetes minuta,* and *Carica papaya* (Muzemu, 2013); cheese wood, lemon-scented gum, ginger, lime, mint, and tobacco (Longe, 2016); and ethanol extract of *Azadirachta indica (A. indica), Chenopodium ambrosioides, Melaleuca lanceolata,* and diatomaceous earth (Dekeba et al., 2016).

The financial considerations for developing ASF are significant. The market for ASF is driven by changes in the pattern of food consumption which are influenced by migration to urban centers, the growing desire of consumers to have tasteful, nutritious, and sustainable products. Combining traditional and new processing technologies can lead to a more diverse market that can enhance the nutrients that are provided by the consumption of ASF.

There is an urgent need to estimate the ability of entrepreneurs dealing with ASF in the production of new processed products and methods to supplement traditional ASF in terms of both nutritional quality and quantity. The use of different processing for ASF product development offer benefits such as oxidation stabilization, combining different food components and creating

higher nutritional equivalents of traditional food products, all of which increase the level of consumer acceptance and broadening consumer categories.

As an example, the rediscovery of a new generation of goat and sheep meat products as functional foods and eating quality is an exciting food research field, answering to the constant innovation requirements by the meat industry. Several possibilities exist to process sheep and goat meats to make them more diversified and appealing to the market. Methods such as dry aging, dry curing, high pressure processing, conventional cooking and fermentation have significantly expanded the types and varieties of foods available in markets. Nonetheless, there is a need to ensure that micronutrients such as iron, zinc and vitamin A are not lost during food processing. For example, up to 90% of vitamin A used in food fortification is absorbed, but 40% can be lost during food processing and storage. These losses are due to vitamin A sensitivity to light and oxygen, which positions packaging as key player in ensuring vitamin A availability. Food fortification could be expensive and demands high technological input, which may not be readily available for food entrepreneurs, but application of the best available packaging and storage practices can help tackling micronutrient deficiencies at business level (Ohanenye et al., 2021).

Teixeira et al. (2020) reported that starter cultures, spices, essential oils, and other additives in meat processing, sheep and goat products can be used as functional health-promoting foods and can also improve the shelf life, product color, and reduce the lipid and protein autoxidation. For example, qwanta, is a traditional air-dried meat product in Ethiopia, which is spiced and dried, with a shelf life of around 12 months that are commonly consumed and used in African countries as a complementary source of protein and support the nutritional status of populations at risk for undernutrition (Teixeira et al., 2020). So, development of ASFs with enhanced properties contribute to better utilization of by-products across the food supply chain, reduce the waste volumes, and improve nutrient composition of diets using locally available ingredients.

Retooling food processing techniques with market-driven food fortification for the improvement of the essential micronutrient contents of foods to enhance the nutritional and health benefits with minimal risk to health will open up new opportunities for entrepreneurs to produce functional food, enhance food safety, and to make them more diversified and appealing for consumers.

Capture the Potential of Neglected and Underutilized Animal-Sourced Food

Neglected and underutilized species (NUS) are useful species of plants, animals, fungi, insects, and fish, to which little attention is paid or which are largely overlooked by researchers, educators, breeders, extensionists, and policy makers. Some of these species have been domesticated by local communities, others are gathered from the wild, but their cultivation and wider use are constrained by the lack of awareness, poor investment in their development, and insufficient human and institutional capacity, among other factors (Temu et al., 2016). While drawing extensively on promoting underutilized crops and trees, researchers also seeks to broaden the perspective to include other kinds of species, including animals and insects—neglected and underutilized animal-sourced food (NUASF) that can play a vital role to improve resilience of nutrition vulnerable communities (Borelli et al., 2020).

According to FAO, promising neglected and underutilized species (NUS) that are nutrient dense, climate resilient, economically viable, and locally available or adaptable have been prioritized as Future Smart Food and have a central role to play in the fight against hunger and malnutrition (FAO, 2018). While traditional foods of animal origin are often unaffordable in low-income households, various neglected products can offer an alternative source of macro and micronutrients, vitamins, protein, energy, and fiber. Globally it is estimated that there are over 12,000 edible species of plants and animals that are currently neglected and underutilized. Many of them are highly nutritious and some of them can withstand floods and droughts and therefore are useful for climate change adaptation. For instance, examples of NUASF used for food in Africa are rodents and insects like agave worms (*Hypopta agavis)* and Mopane worms (*Gonimbrasia belina*) (Kelemu et al., 2015).

Rodents are the most numerous and diverse group of mammals. In Africa, rodent species commonly utilized for meat include the cane rats (*Thryonomys swinderianus*), African giant pouched rats (*Cricetomys* spp.), porcupines and some species of rats and mice (*Mastomys natalensis*, *Arvicanthis niloticus*, and *Gerbilliscus* spp.). Guinea pigs (*Cavia porcellus*) are reared in cages for food in both urban and rural areas. However, much as utilization of rodent meat is widespread, this is an underutilized or neglected source of protein in the continent. To harness rodents as a major source of meat, there is need to encourage people to rear them in captivity, process, and package the meat for wider distribution to consumers. According to a study by Kasolo et al. (2018) three main rodent species *T. swinderianus*, *Cricetomys* spp., and *C. porcellus* have the potential of non-traditional farming animal.

A good scope exists to increase productivity and income for entrepreneurs that are experiencing significant challenges in the food market. Capacity building potential related to NUASFs is expected to empower local food systems by offering diverse food items, establishing new value chains, and processing methods that can reduce the economic risks associated with price and market for livestock production. As an example of species with underutilized livestock potential for growing entrepreneurs is water buffalo. The global population of water buffalo is ∼194 million heads, an increase of 18 million over the last 10 years. These animals are important sources of milk and milk products, meat and meat products, horns, and skin and serve as an important source of farm power. Because of their adaptability to hot and humid climates, the water buffalo can positively address the challenges by climate change, increasing traditional livelihood, and support poverty alleviation, and food security (Minervino et al., 2020). Water buffalo can use lower quality and less digestible feeds and grazing options, making them easier to maintain on locally available roughages. The

water buffalo is considered an efficient converter of poor-quality forages into high quality milk and meat. In addition, they have advantages over cattle such as resistance to common bovine diseases, quality milk and meat products, and outstanding body weight gain (El Debaky et al., 2019). It is important to evolve species management based on ecologically sustainable ranching practices. It is especially important to focus on the fact that the loss of wildlife may threaten the food security of many marginalized areas since the farmer-forager communities that utilize these NUAFS are isolated from markets and depend on bushmeat as their primary protein source (Eves and Ruggiero, 2001).

The generalized drivers for commercialization of NUASFs in high geographical, biological and agroecological diversity, strong traditional and indigenous knowledge, gradually increasing consumers' awareness about health and food quality, market potential for niche commodity, off-season production potential, increasing competitiveness against imports, incipient diversification in agriculture, growing climate-smart practices and technologies, and increasing focus on value chain development.

Apply Synergy of Innovative Technologies and Existing Practices

Innovations around food safety are being developed at an unprecedented rate, some of which could be deployed in the next decade (Barrett, 2020; Robert, 2020; Siegrist and Hartmann, 2020). For instance, plant-based packaging is "the already ready technology" that is available in many LMICs and the expansion and improvement in this approach could booster progress toward safer and more sustainable food system. Plant-based packaging for entrepreneurs is suggested to focus on local bioresources, incorporating socio-economic and cultural aspects. This is particularly applicable for businesses of many remote, marginal communities that have limited access to external production inputs.

According to Herrero et al. (2020), among the future technologies with transformation potential in packaging are: molecular printing, advanced sensors, artificial intelligence, big data, farm-to-fork virtual marketplaces, intelligent food packaging, Internet of Things deployment, nanotechnology, robotics, surface-enhanced Raman spectroscopy (SERS) sensors, smartphone food diagnostics, traceability technologies, biodegradable coatings, drying/stabilization tech, food safety tech, microorganisms coating, nanocomposites, sustainable processing technologies, personalized food, 3D printing, and the implementation of a circular economy (Herrero et al., 2020). All the above innovations improve food quality, nutrient retention for entrepreneurs (Stilgoe et al., 2013; Preston and Lehne, 2017). However, many of these state-of-the-art technologies are not present or easily accessible by small and medium size businesses in Nepal, Senegal, Ethiopia, and other LMICS.

There are a variety of indigenous plants that may be sustainably used as raw materials for the manufacture of plant-based packaging. In Nepal, the plant *Phanera vahlii* is widely distributed in the forest area. The leaves are rich in various quercetin flavonoids and known to exhibit antimicrobial, antioxidant, anti-inflammatory, and antidiabetic effects. It is a common practice for small hotels and butcher shops in villages to use the leaves as packing material for cooked food, sweets, and meat. The cone-shaped leaf wraps are also used during the steam cooking of millet flour. The food wraps not only enhance the aroma of the steam cooked food but also extends their shelf life (Kora, 2019).

Another example is *Shorea robusta* (Sal in Nepali). Sal is one of the major commercial species of timber that is primarily used for construction purposes, fuel (cooking), and has been used for treating intestinal infections (Baral et al., 2020). It is a large, deciduous, highly regenerating, valued tree. The leaves are a rich source of various flavonoids and exhibit antiobesitic, anti-inflammatory, antinociceptive, antibacterial, antipyretic, analgesic, anthelminthic, alexiteric, and wound healing activities (Merish et al., 2014). The leaves have special properties such as water resistance, rigid structure, and color retention. There is a very high potential for making different types of plates and packaging from these leaves, they are extensively used for packing breakfast, meals, and groceries. The Nepalese commonly use these leaf plates on different occasions such as marriage parties, various local rituals, worship ceremonies, and festivals in both rural and urban areas. Since the raw material for this product is locally available in ample quantity, rural labor can be employed and there is no need for extensive capital investments to use it. Using the leaves to make leaf plates in different sizes and shapes can be done with manually operated machines and is a prospective enterprise for growing food businesses since most of these plates come to Nepal from India. Presently, three types of plates are being made by the rural women's groups. On average, it is estimated that there is ∼50% after production costs. An analysis of the maximum margin obtained for producing these plates indicated that medium size plates (*tapari*) provided the greatest net income. It was also estimated that the value addition by mechanized pressing of raw Sal leaf plates could increase income by 96.40% and employment by 50 mandays/household/year (12.50%) (Islam et al., 2015). The growth of this industry is an example of the strong downstream impact growing food businesses can have on local economies.

The capacity building potential of plant-based packaging for entrepreneurs include the generation of employment opportunities for people living in and around the areas of plant diversity and business income generation by generous profit margins. The plant-based packaging industry can also support the production and use of locally available renewable resources. Supporting plant-based packaging may also lead to innovation and increase local technology that will grow the market for these products and continuously provide them throughout the year. These plant-based solutions can provide opportunities for retailers too and support ingredients to packaging, and help monetization of ecosystem services delivery. The economic incentives are then cycled back by the need to invest in growing agricultural production of plants to keep the industry sustainable.

Activity promotion related to the collection, processing, and sale of plant-products are prospective interventions for entrepreneurships contributing to food safety. The utilization of local plant material is cost-effective, labor-efficient, gender equal, environmentally friendly, time-tested, situation-specific, practical, and flexible. Implementing best practices and conducting training activity on the efficient use and management of local plant resources will contribute to a maintenance and evolvement of safe and sustainable food system by traditional knowledge and practice.

Introduce Digital Geotechnologies for On-Going Management

Food safety information along the value chain is often diverse in terms of spatial scale (national, regional, local levels), how it is collected (data sources, data extraction methods), and presented since graphing and analyzing software and usually belongs to different stakeholders. There are also numerous agencies that have food safety information which are not always synchronized. These agencies include government agencies, research institutions, insurance companies, health care professionals, and industry. Moreover, in LMICs food system information is also considerably more variable, changing throughout diurnal and seasonal cycles. This heterogeneity of reporting data provides very little coordinated guidance to entrepreneurs and hinders effective transactions of food safety measures into practice. In order to provide efficient on-going management for food safety and nutrient retention, food businesses need consolidated information with quick access for decision-making for the prevention of food hazards and to prevent nutrients loss.

While reporting of food safety issues is limited, entrepreneurs need a reliable source of information about food hazard hotspots and business-related adverse events. Geographical Information Systems (GISs) can be an unraveling solution. GISs relates informational data to a geographic location and can be dynamically used to grow food businesses. GIS can help to aggregate, analyze, and present food safety data in a comprehensive and communicable way that are relevant to specific business purposes. At the level of food production, it can provide data on quantitative and qualitative post-harvest food losses for specific food group. GIS can also provide spatial correlations between business actors in the supply chain to improve profit margins and support safety standards by calculating more efficient delivery routes, identify the location of storage facilities and retail locations, and providing data for reports on performance metrics. This knowledge will also allow businesses to demonstrate compliance with regulatory requirements, evaluate trends, and make management decisions. Integrating digital geotechnologies offer the potential to triangulate multiple data sources, further improving knowledge and understanding of entrepreneurs' interactions with their food environment. Furthermore, the market-driven needs for implementation of standards ISO 22000:2018 Food safety management systems (ISO, 2018) may also be reinforced by GIS to generate and manage large amount of data with regard to food safety. When it comes to the field of food safety, the GIS market is expected to grow in the coming years since rising investments by government organizations in GIS technologies and growing demand for enterprise GIS solutions (Merem et al., 2019; Tomita et al., 2020).

In terms of growing food businesses, GISs can be used for logistics and traceability to identify vulnerable areas in terms of monitoring and evaluating time and temperature within food safety procedures. GIS can also help build clusters and identify the best location for producers and food businesses. It can support the transportation of food and map optimized routes for delivery systems. At the consumer level, GIS can assess spatial accessibility by consumers to grocery stores selling fresh produce, to map dynamically the spatial distribution of fresh produce contamination and quantify its public health impact (Beni et al., 2011). The trend of utilizing GIS based traceability systems in food chains and networks is increasing, which facilitates to minimize the production and distribution of unsafe and low quality food products (Gölge and Türk, 2019).

According to Environmental Systems Research Institute (ESRI), businesses that have implemented GIS are benefiting from increased supply chain efficiencies through linear network functionality including reducing product storage times, better delivery routing and scheduling. These up-to-date asset management activities all work to strategically release investments and return profits faster. An example is the application of GIS that was used to analyze the route and optimal location of egg supply chain in south Chennai, India that led to identifying the need to add four new distribution centers reducing the traveling distance by 25 miles per day, resulting in a about 27% decrease in expenditures for distributors (Krishnaveni et al., 2017).

Although GIS solutions continue to evolve rapidly and large business operators are able to introduce them, it is expected that investment costs and lack of internal qualification keep many food business operators from adopting these solutions. The goal should be to make these systems scalable and available to smaller businesses so they can access these GIS tools to improve food safety and quality, achieve regulatory and certification requirements, and enhance overall business performance.

FINAL CONSIDERATIONS

The results of the limitations review offer deeper understanding of enabling food safety entrepreneurship along the supply chain. The proposed insights provide potential engagement of entrepreneurs along four different pathways to accelerate better access to safe and nutritious foods for populations. These insights have the capacity to: commercially benefit entrepreneurs' outcomes across various food landscape, promoting modern trends impacting food industry in 2020–2021; be matched and scaled in different political, financial, social, and environmental context; deliver impact to stakeholders across food systems, including processors, distributors, and consumers.

To interevent successfully there is a first step needed for businesses—clarification where opportunities lie for them.

The implication here is that if the local context in which businesses operate influences the food safety practices employed, intervention programs that acknowledge the influence, and consequences of local context may be more effective than those currently suggested.

AUTHOR CONTRIBUTIONS

YV and DT developed the study concept. YV, DT, TC, and JB conducted the study, including data collection, and analysis. DT and TC approved the final version for submission and agreed to be personally accountable for their contributions and for ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated, resolved, and documented in the literature. All authors approved the final version of the manuscript for submission and participated in the generation of study design.

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