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Upscaling of traditional fermented foods to build value chains and to promote women entrepreneurship

by
Valentina C. Materia
Anita R. Linnemann
Eddy J. Smid
Sijmen E. Schoustra

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About the authors

Valentina C. Materia has a PhD in economics and is an assistant professor in Innovation and Entrepreneurship with the Business Management and Organisation Group at Wageningen University in the Netherlands. As an applied economist who developed an interest in innovation as connected to organization theories, agricultural economics, institutional economics, business management and entrepreneurship, Valentina's research focuses on aspects of governance in the transition towards sustainable food systems; women's entrepreneurship in challenging environments; and the dynamics and organization of innovation in agri-food supply chains.

Anita R. Linnemann is an associate professor with the Food Quality and Design Group, at Wageningen University. The ambitious aim of her research is the development of food technological solutions to enhance nutrition security in developing countries, in particular at the "base of the food pyramid", in sub-Saharan Africa. To this end, Anita applies a consumer-oriented perspective in combination with local food resources and tailor-made food technological practices. Moreover, she takes the entire food production chain into account to ensure that the food system becomes as sustainable as possible.

Eddy J. Smid is a professor with the Food Microbiology Group at Wageningen University. His work focuses on non-GMO strategies to steer and control starter culture functionality. Biodiversity mining, population dynamics and adaptive evolution strategies are being applied to achieve the desired culture properties which produce fermented food products with novel functionalities. Eddy has broad expertise in food microbiology, microbial ecology and biotechnology.

Sijmen E. Schoustra is cross-appointed between the University of Zambia and Wageningen University, where he holds a position as associate professor in the Department of Plant Science. Sijmen's main expertise is in microbial ecology and evolution. He uses experimental evolution to study how organisms adapt to new challenges and stable eco-systems. To accomplish this, he uses traditional fermented products from Zambia, which contain complex microbial communities and filamentous fungi, as experimental model systems. The model system of traditional fermented foods has initiated many interdisciplinary projects, linking to food fermentation, human nutrition and health and to women's entrepreneurship. These projects aim to promote traditional fermented foods as a means to ensure food and nutrition security.

Contents

Abstract

To date, many efforts to eradicate hunger focus on a food systems approach and the improvement of local food processing, of which the optimization of the accompanying value chains is an important aspect. In Africa in particular, the agrifood sector holds great potential for bottom-up entrepreneurship, with its potential to create jobs, generate innovations and serve as a vehicle for economic and social empowerment of women and youth. Many local and traditional foods are nutritious and widely attractive, yet have not reached the broad range of potential consumers due to small-scale processing and a lack of effective value chains. Among the local foods, traditional fermented foods are of special interest. Fermentation is an ancient processing technique that relies on the activity of microbes to transform raw materials into attractive products with increased food safety, commercial value, nutritional value and health features and improved sensory attributes. Small-scale fermentation activities represent an important economic opportunity, particularly for women: entry barriers and start-up costs are low, no possession of particular assets is required, and it can be combined with domestic responsibilities. Despite the obvious benefits, traditional fermentation remains a neglected, small-scale and underexploited practice in many countries, presenting a missed opportunity for the promotion of food and nutrition security and livelihoods. In our contribution, we elaborate on how the existing traditional processing of non-alcoholic fermented foods can be upscaled while enhancing and exploiting functional food properties and strengthening local value chains through fostering women entrepreneurship.

Keywords: food system; traditional fermentation; food safety; nutritional value; women entrepreneurship; women empowerment

Scope

To date, many efforts to eradicate hunger focus on a food systems approach, including attempts to increase agricultural production, process various levels of raw materials and supplementation and fortify foods to combat micronutrient deficiencies (Nkonde et al., 2018). Within this context, the improvement of local food processing and the optimization of the accompanying value chains is an important yet underutilized opportunity to improve nutrition and livelihoods. Fermentation is an ancient processing technique that relies on the transformation of raw materials by microbial activity. The use of traditional locally processed fermented foods to improve nutrition and livelihoods is the focus of this paper.

1. Introduction

Among processed and unprocessed local foods, (traditional) fermented foods are a special category because they rely on microbial activity as low technology processing. Through transformation by a diverse community of microbes, value is added to raw materials, which includes prolonged shelf life, improved taste, increased nutritional value, commercial value and health benefits (Aworh, 2008; FAO, 1998, 2011; Tamang et al., 2016). In this way fermented products offer advantages to both sellers and consumers by reducing food losses, improving diets and health and promoting livelihoods (Aworh, 2008; FAO, 1998, 2011; FAO/WHO, 1996). Many traditional fermented foods are processed on a small scale (Anukam and Reid, 2009; Holzapfel, 2002; FAO/WHO, 1996) and represent an important economic opportunity, particularly for women (FAO, 2011): entry barriers and start-up costs are low, no possession of particular assets is required and fermentation is combinable with domestic responsibilities. The contribution of such products to the livelihoods of women and the marginalized is therefore important (FAO, 1998; FAO/WHO, 1996). With appropriate access to inputs, the most marginalized people in a society can contribute to the food security of their families and communities and increase their independence and achieve self-esteem through income generation (FAO, 2011). Local and traditional foods are often more or equally nutritious as their global counterparts. Yet, their nutritional value has often not been measured, hampering the inclusion of local foods in interventions or policy to promote food security (Chileshe et al., 2020).

The global popularity of fermented foods exemplifies the opportunities for (traditional) fermentation to become a diversification enterprise. Fermented products are part of many social and cultural events; demand for such products – that contribute to the cultural identity of populations – is found not only in traditional rural areas, but also in large urban centres as a result of traditions and rural migration (Aworh, 2008). Traditional fermented foods have in fact inspired commercial companies to develop foods that resemble local foods but lack many of the properties of traditional foods (Katz, 2016). Most commercial processes rely on fermentation by a simple instead of a diverse microbial culture, which limits the additional shelf life, nutritional and health benefits (Holzapfel, 2002). We argue that current commercial upscaling also leaves current traditional processors behind, impeding the long-term development of rural poor. Making fermented foods the object of efforts to stimulate small-scale producers – especially women – entrepreneurship in this field allows for a direct and long-term effect on food and nutrition security by making fermented foods more available. Indirectly, it also boosts income generation which helps to support livelihoods (FAO, 2011).

Traditional fermented foods can be considered moderately processed foods. As outlined in a parallel IFAD contribution on the *Role of industrially processed foods and food systems transformation* (Van Damme et al., 2021), levels of processing range from unprocessed raw products to moderately processed to highly or ultra-processed foods. Unprocessed raw products are consumed as raw ingredients. Highly or ultra-processed foods are where raw material undergoes multiple processing steps that can only be performed at an industrial scale. These foods are usually a mix of various ingredients. Moderately processed foods are products alternated from household level processing, including processes of cooking, cleaning, milling and, in the case of the foods that are the focus of this contribution, fermentation.

In this contribution, we elaborate on how existing traditional non-alcoholic fermented foods can contribute to food and nutrition security in focal African countries and how this can be adopted by local actors in the food system. Specifically, we focus on investments and specific interventions that form a combination of

technological aspects of upgrading traditional processing while enhancing and exploiting functional food properties and strengthening local value chains to place current local processors at the centre stage through fostering women entrepreneurship.

The article is structured as follows. Section 2 highlights the properties and benefits of fermented foods from a food systems perspective (drivers, value chains, outcomes). In section 3 we present three product examples and describe what would be required for their upscaling. The three products are representative of many traditional fermented foods in Africa and cover important milk and cereal-based traditional fermented foods: Mabisi in Zambia, Akpan in Benin and Mahewu in Zimbabwe. These fermented foods do not only possess nutritional properties that make them highly valuable as a means to guarantee food security: they also represent tradition, cultural embeddedness, identity to those consuming them and opportunities for empowerment to those producing them (mainly women). This choice covers a range both in terms of the level of formalization from traditional towards standardized processing and of the locations of production and consumption and various levels of involvement of (institutional) actors. Section 4 highlights what is needed to implement upscaling at the level of technological innovations as well as building effective value chains that empower current women processors.

2. Fermentation in the context of food systems and the role of local women processors

2.1 What are (traditional) fermented foods?

Fermented foods are foods or beverages made through controlled or purposeful microbial growth and enzymatic conversions of raw materials into safe, highly nutritious and sensory attractive products (Figure 1) (Smid and Hugenholtz, 2010; Marco et al., 2017). Fermented foods include acidic non-alcoholic foods that are consumed by all age groups, as well as alcoholic beverages. Raw materials include various cereals, milk, beans and meat or fish. The process of fermentation has been applied for centuries as artisanal low-cost and low-technology processing performed at the household level. In more recent times, the process has been industrialized for several well-known products, such as yoghurt, cheese, beer and wine. Here, we define traditional fermented foods as those whose processing has not been formalized and has not been upscaled to an industrial scale.

Due to the microbial activity, fermented foods have at least four unique properties that distinguish them from other foods in the human diet and that make them particularly suitable to promote food and nutrition security. Firstly, fermentation prolongs the shelf life of the raw materials used due to the increased acidity or presence of alcohol, combined with the excretion of compounds (such as bacteriocins) that specifically inhibit pathogenic bacteria (Nout et al., 2005). Acidity and/or alcohol can completely block the growth of pathogenic bacteria and remove pathogenic bacteria present in the raw materials. Secondly, fermentation leads to a richer taste and improved organoleptic properties of the raw materials. Fermenting microbes generate a wide range of aroma compounds that greatly enrich the raw materials (Thierry et al., 2015). Thirdly, fermentation increases the nutritional value of the raw materials. The action of microorganisms generally causes food components to become better available in the human digestive tract, increasing the nutritional value of the raw materials. This applies to carbohydrates as the main source of energy, but for instance also to essential micronutrients like iron and zinc (Marco et al., 2017), which fall short in the diets of many urban and rural people. In addition, microbes can synthesize B-vitamins leading to in-situ enrichment of the raw materials (Smid and Hugenholtz, 2010). Fourthly, the consumption of lactic acid bacteria (probiotics) and their metabolites present in fermented foods modulates the composition of intestinal bacteria leading to shifts to healthier composition, preventing disease and stimulating the immune system of its consumers (Kort and Sybesma, 2012).

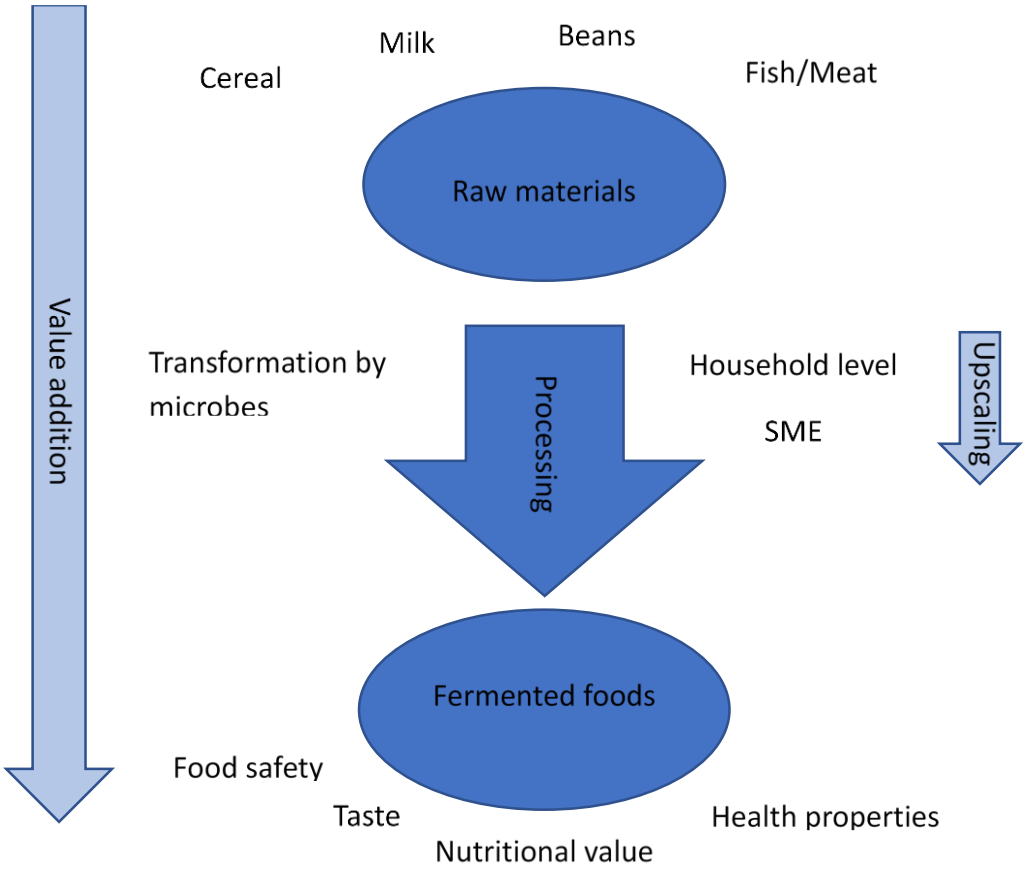


Figure 1: Transformation of raw materials into fermented foods. Fermented foods are the result of the transformation of raw materials into processed foods. Raw materials include a wide range of primary agricultural products. Through processing, value is added in terms of safety and other functional properties that increase the monetary value of the raw materials. Processing of traditional fermented foods is mainly performed at the household level and has the potential for upscaling to small and medium-sized enterprises (SME) and/or industrial scales.

Fermented foods, including traditional fermented foods, contribute to local food security and livelihoods (FAO, 1998, 2011; FAO/WHO, 1996). While industrially produced fermented foods are well-known, lesser-known traditionally fermented foods are also widespread across the globe. These are mostly produced in the artisanal way at the household level. Fermented foods carry many nutritional properties (e.g. fermentation plays an important role in the nutrition of infants and young children in Africa; Adesulu and Awojobi, 2014), they can improve the flavour and appearance of food (FAO, 2011) and are often considered part of the national heritage of a country (Aworh, 2008; Holzapfel, 2002; FAO, 1998; FAO/WHO, 1996; FAO, 2011, 2011b, 2011c). The indigenous knowledge of producing fermented food and beverages has in fact developed over a long period of time and fermentation techniques have become integral components of many cultures (Aworh, 2008). The four properties outlined in the previous paragraph make traditional fermented foods highly relevant to promoting food security. Firstly, the prolonged shelf life of raw materials reduces food losses, for instance of highly perishable products such as raw milk, as it hinders the growth and proliferation of pathogenic microorganisms. Secondly, the improved taste and other organoleptic properties increase the commercial value of the raw materials, providing opportunities to improve the livelihoods of its producers due to greater sales opportunities. Thirdly, the increased nutritional value helps to balance diets that are otherwise constrained by limited (bio)availability of micronutrients and the presence of anti-nutritional factors, such as the lactose in milk, that can be removed by fermentation. Fourthly, the indirect health benefits promote the general health of consumers and prevent the spread of disease.

Microbial activity is central to the processing of the raw materials. Traditional foods are fermented by a largely uncontrolled mix of a variety of different fermenting microbes, while most industrial processes are

fermented by a controlled mix of a few bacteria (Katz, 2016). Fermentation with complex microbial communities provides higher levels of intrinsic stability to the microbial community due to stabilizing interactions between species that prevent and inhibit the proliferation of invader strains, including pathogenic strains (Erkus et al., 2013; Butler and O'Dwyer, 2018). Further, the complex microbial community likely contains natural probiotic strains enhancing the health benefits from their consumption (Kort and Sybesma, 2012; Groenenboom et al., 2019). Thus, since traditional fermented foods entail a complex microbial community consisting of many microbial species and the industrial products have a simpler and far less diverse microbial community, the advantages above apply more to the traditional than the industrial foods.

2.2 Traditional fermented foods in a food systems framework

Fermented foods and beverages have long been an important part of the human diet in nearly every culture on every continent (Tamang et al., 2020; Hesseltine and Wang, 1967). Despite showing common features, such as supplying stable and significant sources of proteins, vitamins, minerals and other nutrients (Tamang et al., 2016, 2020; FAO, 1998, 2011), many differences exist with respect to substrates and products (FAO, 1998, 2011) and the types of microbes involved in producing fermented foods and beverages globally (Hesseltine and Wang, 1967). Some fermented foods appear to have originated and developed in particular locations (Tamang et al., 2020). For example, cultured milk, cheese and fermented dairy products evolved throughout the Middle East, Europe and India, namely wherever pastoral agricultural practices and animal husbandry prevailed and therefore milk from cows, sheep, goats and other animals was often available. China, Japan, Korea and other Far East regions instead have more limited animal agriculture and therefore the fermented foods that evolved there (and generally in Asia) are more commonly based on rice and grains, soybeans, vegetables and fish as the primary substrates (FAO, 1998; Tamang et al., 2020). Fermented cereals, roots and tubers (e.g. cassava) are instead consumed as dietary staples throughout Africa, but also Asia and Latin America (FAO, 2011); they can take various forms including breads, porridges, gruels and pickles. Moreover, a wide range of grains, fruit and vegetables are also used to manufacture beverages, both non-alcoholic (e.g. tea, coffee, juices, nectars, syrups and carbonated soft drinks) and alcoholic. The alcoholic beverages are often consumed on special occasions, including festivals (FAO, 1998, 2011; Chelule, 2010). In Africa, cereal grains endemic to specific regions, including millet, sorghum, maize and wheat, are common substrates of food fermentation (Tamang et al., 2020). Moreover, fermentation by-products (e.g. rice husks) can be safely fed to supplement livestock nutrition, thereby further strengthening the livelihood system (FAO, 2011). Similarly, the by-products of brewing, such as "brewers grains" and dried yeast, provide a good source of undegraded protein and water-soluble vitamins (FAO, 1999). By means of enhancing livestock nutrition and improving their health, other costs (e.g. veterinary fees and costs related to sickness and mortality of livestock) can be greatly reduced (FAO, 2011).

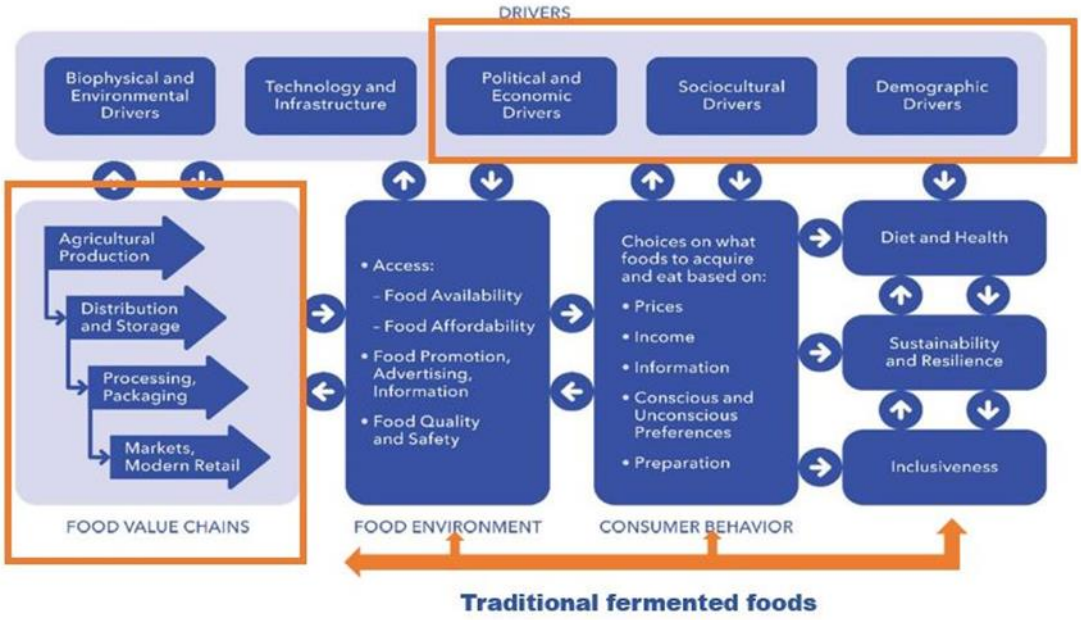


Figure 2: The value added of fermented foods within the IFAD food system approach.

Source: our elaboration on Arslan et al., 2020

As highlighted when applying a food systems approach (see Figure 2), fermented foods can greatly contribute to the livelihoods of rural and peri-urban populations through enhanced food security and income generation via a valuable small-scale enterprise option (Aworh, 2008; FAO, 1998, 2011) and empowerment of the actors involved in the related value chains. Fermented foods can in fact contribute substantially to food security and nutrition, especially where food shortages pose serious harm to the most vulnerable (FAO/WHO, 1996; FAO, 1998, 2011; Holzapfel, 2002). In this sense, fermented foods provide many opportunities towards meeting the growing world demand for food (FAO, 1998, 2011). During the famine in 1983-1985 in Sudan, for example, people survived by producing specific traditional fermented foods (such as Kawal), whose production was benefitting from one of the most adverse weather conditions ever. Sudan is in fact possibly one of the driest and hottest countries in Africa and women (the main producers) could make use of this free source of solar energy to contribute to the livelihood of their communities (FAO, 2011). Therefore, in addition to supporting the expansion of food production in difficult times and challenged contexts, fermented foods can contribute to improving access to food, an important component in the thinking about food security (van Berkum et al., 2018).

The global popularity of these foods creates many opportunities for fermentation to become a diversification enterprise (FAO/WHO, 1998; FAO, 2011). Fermented products are part of many social and cultural events. Their demand is found not only in traditional rural areas but also in large urban centres as a result of tradition and rural migration (Aworh, 2008). With many workers moving from rural to urban areas on a daily basis, a ready market can be exploited with such products bought from rural areas and taken to cities for meals or bought from retailers in urban areas and then sold to daily migrant workers (FAO, 2011, 2011b, 2011c). Generating, identifying and exploiting business opportunities in rural areas provides incentives for especially women to build their future there rather than migrating to larger urban areas (Aworh, 2008; FAO, 2011). This mitigates the pressure on rapidly growing cities and facilitates modern development and better infrastructure in rural areas, which are among the drivers for the transformation of food systems globally. In turn, urban populations benefit by gaining access to much-loved traditional and culturally embedded products that they know from their relatives in rural areas (as outcomes of the food system).

When farmers and small processors produce and sell fermented foods locally (namely, where food systems associated with traditional fermented foods are mainly traditional or transitional; HLPE, 2017), this greatly reduces the dependency of rural and urban populations on food imports (Aworh, 2008; FAO, 2011). As small-scale producers, the majority of whom are women, are active in the production/processing and

diffusion of these foods, fermentation represents an opportunity for enhancing livelihoods (FAO, 1998; 2011). Combined with proper approaches to diffuse knowledge, understanding of hygiene procedures and technical progress in rural remote areas, fermentation has great potential still to be exploited (FAO, 2011).

From an economic and entrepreneurial perspective fermentation is a method to preserve food in areas where preservation techniques (such as cold storage) or hot-holding cannot be used due to a lack of facilities and resources. As such, it has been considered an affordable technology for the preservation of foods (FAO/WHO, 1996; FAO 1998, 2011). The production of fermented foods provides income and employment for millions of people around the world (FAO, 1998, 2011): food processing – namely value added through marketing and processing raw materials – is possibly one of the most relevant sources of income and employment in Africa, Asia and Latin America, more than primary production (FAO, 1998; Adeyeye, 2017; Asogwa et al., 2017). Moreover, fermentation activities are highly combinable with a variety of other traditional and domestic activities (FAO, 2011). The contribution they can make to the livelihoods in particular of women and vulnerable groups (e.g. the disabled and landless poor) is important; with appropriate training and access to inputs, the most marginalized in society can still increase their independence and achieve self-esteem through income generation (FAO, 2011). As activity run off-farm using raw material from agriculture, we argue that food fermentation represents a diversification activity performed in search for other sources of income. The processing of raw material deriving from agricultural activities (e.g. maize, but also milk from livestock) allows for a potential second stream of income for the household (McCullough, 2015). As an economic activity, fermentation has potential in providing a diversified stream of income for a rural household.

Fermented foods are highly appreciated and an important part of many food systems, not just in developing countries, but also in industrialized countries, where a wide spectrum of foods is marketed for the benefit of preservation and safety and also for their highly appreciated sensory attributes (FAO, 1998, 2011). For fermented foods such as beer, cheese, bread and wine produced on a commercial scale, a good understanding of the microbial processes has already been developed (FAO, 1998), while knowledge of many processes in Africa, Asia and Latin America is still poor. Production conditions change from region to region, giving rise to several variations of the same products in terms of both production knowledge and techniques, cultural aspects associated with the production and consumption, and quality and acceptability of these products for weaning purposes (FAO/WHO, 1996). Independently of geographies, processes are not standardized yet though, which neglects the tremendous potential these products have to contribute to the quality and quantity of food available to the worlds' populations.

In sum, in this contribution, we argue that the optimization of a value chain of primary produce by small-holders can be approached by addressing key technological questions, while at the same time providing direct benefits (i.e. food system outcomes) such as increased nutritional content, the improvement of diets of low resource urban consumers, decreased food losses, increased income and livelihood for producers/processors and their families and increased food and nutrition security for processors connecting to rural and urban consumers.

2.3 The role women play in a food system transformation: opportunities from fermentation activities

Fermentation activities by small-scale producers represent an important economic opportunity, in particular for (rural) women who are traditionally knowledgeable of fermentation processes as they are passed down for generations from mothers to daughters (FAO, 2011). By means of processing traditional fermented foods and by their involvement in agrifood related activities, women's contribution to local, national and global food security and economic growth proves to be crucial (FAO, 2011b). In East and Southern Africa, for example, family farming represents the key livelihood strategy in rural areas, accounting on average for one third of the region's GDP and employing approximately 60 per cent of the rural labour force (IFAD, 2018). Women represent half of the agricultural workforce (IFAD, 2018), ranging from just over 40 per cent in Southern Africa to about 50 per cent in Eastern Africa (FAO, 2015). Women play a fundamental role in ensuring food and nutrition security in all countries and make a crucial contribution to the survival of many poor rural households in the region (IFAD, 2018). Women's roles in agriculture have been expanding considerably in Latin America and the Caribbean (IFAD, 2019) too, for example in agricultural labour, where

their average participation rate in the region jumped from 32.4 per cent in 1990 to 48.7 per cent in 2010 (FAO, 2017 cited in IFAD, 2019). Rural women are a key asset for growth in this area. On the one hand, they play a key role in family farming and so contribute to the availability of food and to the supply of fresh produce, raw materials and inputs, as well as to value addition at the local level through rural agro-industries (IFAD, 2019). On the other hand, their important role in preserving biodiversity through seed recovery and agroecological practices is well acknowledged.

In general, rural women produce half of the world's food and, in developing countries, between 60 per cent and 80 per cent of food crops (ICRW, 2008). Women work as both subsistence and commercial farmers and they have multiple and diverse roles and responsibilities. Women work on their own plots and those of others; they work as unpaid or paid workers, employers and employees, and as wage-labourers in both on- and off-farm enterprises (ICRW, 2008, page 5). Traditional indicators of employment in agriculture from a gender perspective show that globally women make up more than 40 per cent of all of those employed in agriculture, a proportion ranging from 20 per cent in Latin America and the Caribbean to around 50 per cent in sub-Saharan Africa and Central, West and East Asia (FAO, 2018). The importance of agriculture as a source of employment is shown in Figure 3 where the share of female employment is also indicated.

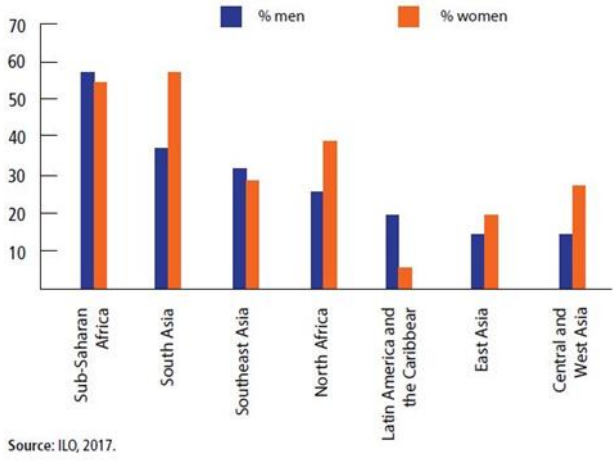


Figure 3: Employment in agriculture (% of employed), 2017 estimates.

Source: FAO, 2018 from ILO, 2017

These indicators (Figure 3) underestimate the extent of rural women's activities because they exclude non-employment work and only capture market-oriented employment. However, in many developing countries agricultural households sustain themselves with a combination of income generated through employment and outputs from non-employment activities (FAO, 2018). Among the non-employment activities, the own-use production of goods and services is an important source of income generation, including subsistence agriculture and household management, as well as formal and informal types of volunteer work or unpaid activities for third parties. Food processing is one of these activities. Non-employment work can represent a substantial share of rural people's workload (FAO, 2018) and informality remains pervasive among women in developing countries (ILO, 2018). An estimated 85.8 per cent of African workers are informally employed (ILO, 2020), which means limited access to social security and few or no rights at work. Where large impoverished rural populations depend on agriculture for their livelihood, these informal activities are most common. Although both women and men in developing countries are heavily engaged in non-employment (own use) production work, women report the highest rate of time per day used in these activities, with a workload substantially higher than men.

In this sense, women exercise a remarkable agency through their everyday work, balancing subsistence, income-generating activities and the establishment of their social networks. We refer to this agency as entrepreneurship (Materia and Dentoni, 2020). In doing this, women and in general rural smallholders, act as key economic agents of change in the food system (Figure 2) and in their rural communities, as producers of food, a source of wage employment and as consumers of food (Arslan et al., 2020).

The role agricultural growth and development plays as a means to address both hunger and poverty has therefore gained a renewed interest (ICRW, 2008) in the last few decades, with an increasing commitment to women farmers and resources to strengthen their roles in the agricultural and rural economy from different organizations, both in the private and public sector. By aiding food production, women also contribute substantially to income-generation activities. For example, women produce, process and store fermented food that is consumed, shared and sold both within and outside their household and community (FAO, 2011).

The role rural development can play in promoting (women and men led) small-scale food fermentation activities for food security is crucial. These business activities involve lower capital investment and rely on traditional food processing technologies (Aworh, 2008; Taiwo et al., 2002; FAO, 1998, 2011). Through the generation of employment opportunities in the rural areas, small-scale food fermentation enterprises reduce rural-urban migration and the associated social problems. These enterprises are vital to reducing post-harvest food losses and increasing food availability (Aworh, 2008). Experiences from Nigeria prove that small-scale food industries, involving limited mechanization of the traditional methods of food processing, offer better prospects for success for those involved (Taiwo et al., 2002; Aworh, 2008). They provide possibilities for replication in the rural areas where the raw materials are produced, whereas full mechanization often results in higher overhead costs. In addition, small-scale plants have the advantage of being able to match processing capacity with raw material supply and are, therefore, less adversely affected by raw material shortages than large-scale food industries (Aworh, 2008, page 4). As a source of considerable innovation, even at their niche level, small-scale businesses make a significant entrepreneurial contribution (Taiwo et al., 2002) in the sense that they serve as agents of change in a market (Robson and Gallagher, 1993), for example by creating more employment opportunities.

Being highly combinable with a variety of other traditional and domestic activities, traditional fermented foods represent an area dominated by women which remains typically very informal and mainly confined to the household level (FAO, 2011). Also from the perspective of a traditional small-scale fermentation enterprise led by women, processing of fermented foods requires low labour inputs, while marketing them enables women to leave the homestead to earn income for both the farm family and importantly for themselves (FAO, 2011). In addition, they gain skills and knowledge from interacting with other actors and women (e.g. customers, other vendors, suppliers and so forth). In this way, women potentially achieve more independence, become more confident, interact with others and gain business and social relations which give them more status in the community and eventually lead to greater authority within their families (FAO, 2011). An example is offered by the Canadian-Dutch fermented food for life project , namely an innovative business model created to encourage local production, distribution and consumption of probiotic yogurt in rural areas of Kenya, Tanzania, Uganda, and beyond. The project provided training in yogurt production, record keeping, marketing and government certification procedures for food safety agencies. As a result of the project, two scale-up pathways were successfully tested and numerous production units were established. Moreover, women who had no significant control over resources or incomes before the project (although they contributed almost 70% of labour in the dairy sector) started leading individually and group-owned production units, reporting greater confidence, better access to financing and greater mobility (Reid et al., 2020).

Moreover, what women earn from fermented foods activities can provide for family needs and increase savings, but also serve as a safety net in case of shocks (related to the women themselves, such as abandonment and widowhood, or to the macroeconomic situation, with the case of climate related events or pandemics). Managing such an enterprise in principle would not require literacy and numeracy, therefore providing for greater inclusivity. Clearly, participation in training programmes on topics such as basic quality and safety would be an incentive to acquire new skills as an enterprise expands its operations since this would also result in a way to increase family income (FAO, 2011).

In sum, we argue that fermented food production and processing offers evident opportunities for fostering entrepreneurship, particularly for women. On the one hand, supporting women and their enterprises in this sector is a way to acknowledge that women entrepreneurship happens every day and in various *social* settings, which can be more important than *business* settings at the enterprise level (Materia and Dentoni, 2020). Social settings can be within the family at the dinner table when discussing fermentation operations led at the household level, when meeting neighbours or other women suppliers, and in general actors of

these foods' related value chains, or during cultural and religious events where these products are bought and consumed. The potential that fermentation activities provide for the food self-subsistence of the household and their communities is enormous, especially considering how fermented foods can contribute to survival in extreme cases (FAO, 2011). On the other hand, fermentation as an economic activity has the potential to expand women's ability to make strategic life choices and by means of this challenge power structures within social systems, especially where culture, norms and beliefs still represent a barrier. In this sense, fermentation as an entrepreneurial activity involves developing a new identity, recognizable to others, as well as gaining resources and rights, achieving well-being, and thus gaining empowerment (Materia and Dentoni, 2020).

2.4 Barriers for small-scale (women) producers to contribute to food security through fermented foods

Globally, among smallholders (small-scale farmers but also pastoralists, forest keepers and fishers), men and women have diverse and often complementary roles related to household food provision (FAO, 2015). Women play an essential role in food and nutrition security through their responsibilities in the provision and preparation of food consumed in the home (FAO, 2015). However, research indicates that in comparison with men, they often bear in general a disproportionate work burden and face constraints that limit their potential (FAO, 2018; ILO, 2018, 2020). Rural women's long working hours correlate to a triple work burden in the productive, reproductive and social spheres, and in contrast to men, their work is mostly unpaid and unrecognized (FAO, 2018). When working in rural businesses with their spouses, women invest considerable time but often do not share decision-making power and may not identify themselves as business owners. This work overload restricts women's well-being and their engagement in activities of value, including remunerative activities (FAO, 2015, page 1). The interaction of work overload with impoverished settings (characterized by poor infrastructure, insufficient local food production, poor access resources and dependency on males for shelter and access to farmland) can restrict women's personal growth and impede them to become empowered to establish an independent means of generating revenue (Reid et al., 2020).

Although the potential for women to contribute to food security by means of producing and processing (traditional) fermented foods is significant, various barriers still exist for local micro and small-scale producers to upscale their traditional processing. In general terms, the globalization of food and the need to feed a growing population has resulted in the adoption of practices which increase productivity at the cost of natural resources and consequently depart from traditions such as food fermentation.

Barriers pertain in general to micro and small economic activities (such as fermentation) and to women's position in their cultures and contexts in particular. Rural small producers often struggle to (consistently) produce a large enough volume of products that buyers might be interested to buy, and even when they cope with volumes, they still cannot afford the high transaction costs connected to finding a market for their produce, with the outcome being that they face difficulties earning a living and competing with other small producers. Moreover, most micro and small businesses led by women are underrepresented in employers' associations. Consequently, women lack both a voice and representation to raise awareness and advocate for their needs (FAO, 2010).

Those accessing a market often lack opportunities to negotiate better terms of trade for their products, and if they are not affiliated to organizations acknowledged for their aim to support rural development their chances of surviving the competition are minimized. Their lack of power is closely linked to a lack of services, as well as the limited provision and quality of public goods. Moreover, the rapid growth and development of small-scale food industries in many developing countries is hampered by the adoption of inefficient or inappropriate technologies, poor management and inadequate working capital (Aworh, 2008). For instance, small-scale food enterprises rely on locally fabricated equipment: a study of these enterprises in Nigeria identified a lack of spare parts for equipment maintenance and repair as a major problem constraining their growth (Aworh, 2008; Taiwo et al., 2002).

When it comes to women, rural female entrepreneurs also face particular challenges entering new and more lucrative markets and expanding their businesses – although micro and small enterprises might offer

a number of advantages for rural women (such as flexible working hours, working from the household, ease of entry and links with local markets) (FAO, 2010). They are prevented from accessing education and resources, for example, land. Low rates of female land ownership can hinder access to financial assets that are necessary to set up a business. According to FAO (2010) less than 20 per cent of agricultural land holdings in low- and middle-income countries are operated by women (10 per cent in Western and Central Africa and in the Near East and North Africa). Women's entrepreneurship in general is not broadly accepted in many societies, with the consequence that many women face attitudinal obstacles in their starting, consolidating and developing a sustainable business.

Moreover, in the transformation of the agrifood sector in many developing countries we often observe a friction between small-scale women processors being adequately prepared and able to become successful *entrepreneurs* (e.g. upscaling their household production of fermented foods), and the limited opportunities and other constraints that currently exist. For many rural women, entrepreneurship is part of a broader livelihood strategy, often undertaken on a part-time basis where it is difficult to separate production and reproduction tasks as well as market and non-market work. However, being exposed to few employment choices, women often start businesses in highly saturated sectors, low paying and feminized markets (e.g. handicrafts, agricultural, fish and livestock products for local markets) in the informal economy and in low-productivity and low return activities, where they benefit from little or no social protection (FAO, 2010). Food processing is among these sectors, where women currently operate mainly as street or door-to-door vendors.

In addition, women producers, especially in developing countries, still face difficulties benefitting from participation in value chains. Often they are excluded or have their participation restrained in organizations (FAO, 2011b) since they also face challenges such as cultural and legal discrimination. Consequently, they cannot access resources such as productive assets, finance, education and technology, with the result being that they are often concentrated in the less profitable stages of the value chain, struggling to engage in the value chain's more lucrative activities (FAO, 2011b).

In sum, although their contribution is crucial, women at present do not receive globally equitable benefits from their efforts in contribution to food security. In some countries, gender inequality in society, including unequal access to finance, training and mentoring, time burdens, social norms and limited participation in decision making (FAO, 2011; IFAD, 2019) hamper the potential women have to contribute to food security. However, in countries where social, cultural or religious traditions impede women from leaving the homestead or meeting the different actors operating along the value chains of their traditional fermented food products, women can still play an active part in a fermentation enterprise (FAO, 2011). Therefore, when innovative institutional and operational mechanisms and business models are developed to enable small-scale producers, especially women, to seize market opportunities along agricultural value chains, acknowledging issues of gender-based power inequalities and access to choices and resources (FAO, 2011b), then the potential that fermentation can have on enhancing the condition of rural women is fully exploited (Reid et al., 2020).

3. Upscaling of traditional processing: a way forward based on three product examples

Various interventions are required to successfully upscale traditional fermented foods from the household to small and medium-sized enterprise (SME) level in order to reach a high number of urban and rural consumers while engaging traditional processors and upscaling their production with them as actors. Since different traditional fermented foods still share similar characteristics in processing protocols and scale, microbial dynamics and general nutritional features, similar approaches to upscaling can be applied to many of these foods. In this section, we give concrete examples for three traditional fermented foods.

Upscaling small-scale fermentation is a prerequisite to increase not only economic and social benefits from traditional fermented foods, but also to the sustainable development of families and communities (Adesulu and Awojobi, 2014; Bell et al., 2017; FAO, 1998, 2011). So far, due to a lack of specific knowledge, formal fermentation in developing countries still depends on information derived from the advancements and

progress from developed countries and on technology transfer (Bell et al., 2017; Nduko et al., 2017). For example, there is still the need for proven food safety because regulators certify and approve fermentation techniques adopted in many developed countries (Bell et al., 2017). Case-specific interventions are needed to promote traditional fermented foods and their usage at wider level.

Nevertheless, upscaling traditional processing can take inspiration from various examples that exist of fermented foods that have been upscaled from traditional small-scale local processing to standardized industrial processing. These include well known products like yoghurt, cheese, beer and wine. The popularity and success of African traditional (fermented) foods have inspired large commercial companies to engage in upscaling these traditional processes by standardization and more controlled processing procedures. However, most of these current commercial processes rely on a very simplified microbial community (simple defined starter culture), making the resulting products watered down versions of the traditional fermented foods that lack many of their specific and valued functional properties. In many cases, these commercial variants lack the rich aroma and taste and much of the intrinsic food safety properties and nutritional and health benefits compared to the traditional fermented foods. For instance, commercial foods need refrigeration for storage whereas traditional foods can be kept at ambient temperatures for several days. In most cases, upscaling has bypassed traditional processors who have not been engaged in upscaling. Nevertheless, these commercially available industrial products inspired by traditional fermentation illustrate that there is a widespread demand for traditional fermented foods.

Some notable exceptions exist where traditional processing has been formalized and upscaled using the traditional processing methods including fermentation by complex microbial communities containing many species, preserving many of the functional properties of traditional foods. In Europe, these include various microbrew beers and raw milk cheese, demonstrating that when standardized traditional processing is applied (and this could be spontaneous fermentation like with raw milk cheese), highly reproducible outcomes can be achieved and products with desired functional properties can be produced. In a similar way, traditional fermented foods in Africa could be upscaled while maintaining the specific functional properties of traditional foods.

In Africa, although most fermented foods remain processed at the household level, some traditional fermented foods have been upscaled and formalized in their processing. Gari is an example of such a product that is made from cassava and found predominantly in West Africa. Here processing not only adds taste and texture to the raw materials, but it also includes fermentation which detoxifies cassava by removing hydrogen cyanide. Upscaled fermentation includes the addition of defined mixes of microbes (starter cultures) as well as spontaneous fermentation by a diverse mix of bacteria. Upscaling has reached semi-industrial levels, for instance it has been achieved by cooperatives (Irtangwe, 2009; Edward et al., 2012; Bobola et al., 2019).

To exemplify opportunities for upscaling traditional processing while maintaining the functional properties of traditional foods being processed by small-scale processors, we focus on three traditional fermented foods from Africa that have not yet been upscaled beyond traditional processing. These products are Mabisi from Zambia (box 1), Akpan from Benin (box 2) and Mahewu from Zimbabwe (box 3) Figure 4 shows the locations. Mabisi is based on raw milk, Akpan is based on maize and sorghum where after fermentation fresh milk/cream is added, and Mahewu is based on maize and sometimes sorghum. All three products share the characteristics of traditional fermented foods described above in that a complex community of fermenting microbes underlies the transformation of raw materials, they have an extended shelf life compared to raw materials, they do not require refrigeration, they have a higher nutritional value than the raw materials due to higher levels of micronutrients and the removal of anti-nutritional factors and local knowledge attributes health benefits to their consumption, such as preventing diarrhoea (Schoustra et al., 2013; Moonga et al., 2019, 2020; Chileshe et al., 2019, 2020; Phiri et al., 2020). Traditional Mabisi has not been formalized or upscaled so far. Mahewu has to some extent and for Akpan, some protocols for upscaling of traditional processing exist.

The three products (Mabisi, Mahewu and Akpan) are produced by local small-scale processors; Mabisi mostly in rural areas, Mahewu in rural and urban areas and Akpan mostly in urban areas. Producers mainly produce these products for home consumption as well as for local sales at informal markets. Currently, consumers are located close to the processors. Consumers enjoy the traditional versions of fermented

foods, yet at present many consumers buy the available commercial surrogates since traditional foods are largely unavailable in urban areas. Surveys have shown that consumers in Lusaka (85 per cent of low-income consumers and 72 per cent of middle-class surveyed at shopping malls) would prefer the traditional Mabisi product if the product were available. Similar popularity exists for traditional Mahewu and traditional Akpan among consumers in large urban centres. For each of the products, technological aspects of upscaling include certification and standardization to meet the demands of consumers and logistical interventions to build value chains while focusing on current local processors as the main actors in upscaling. Below, we outline various aspects of technological upscaling followed by a reflection on engagement of current local processors.

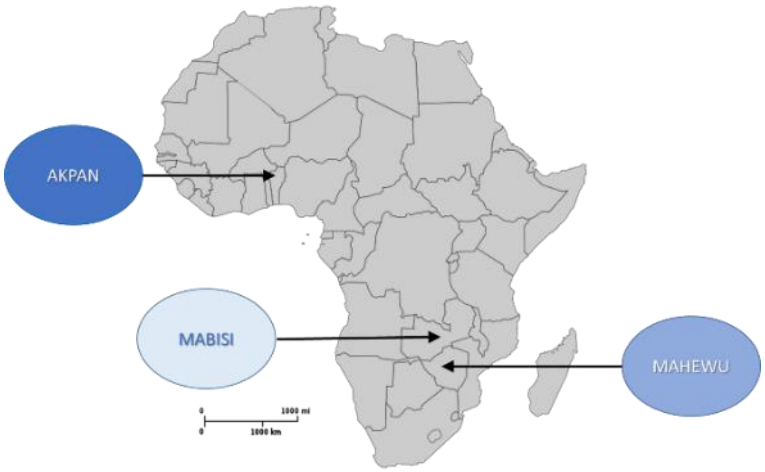
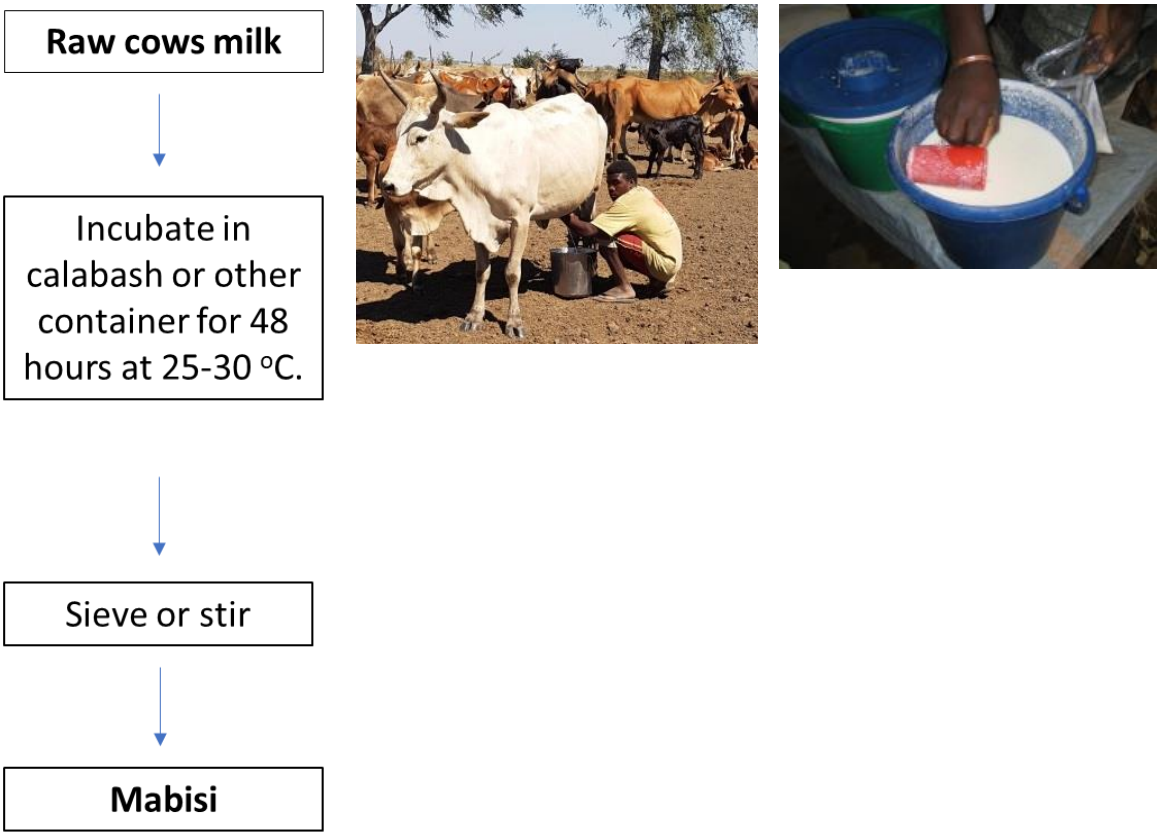


Figure 4: Traditional foods with small-scale processing: Mabisi in Zambia, Akpan in Benin, and Mahewu in Zimbabwe

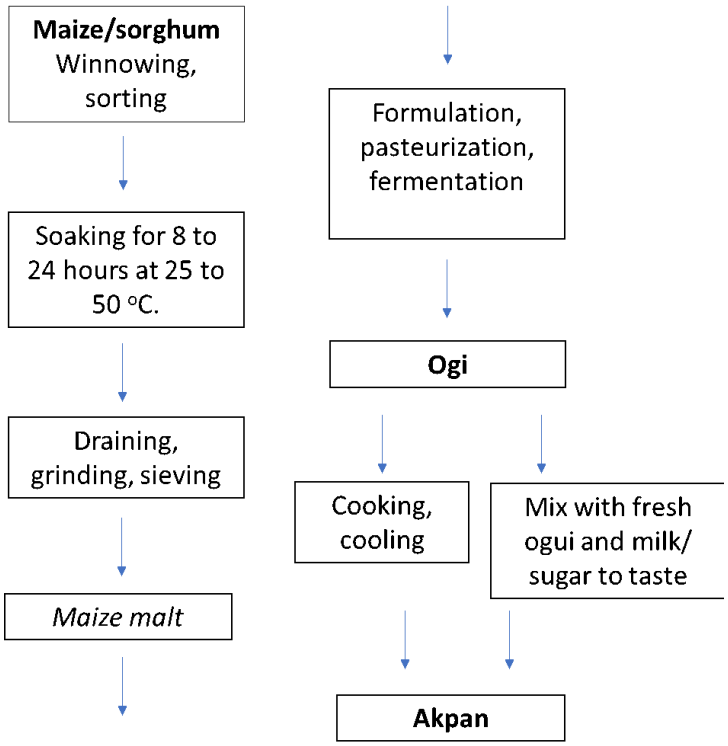
BOX 1: Milk-based fermented food from Zambia: Mabisi

Mabisi is based on milk. It is made from raw milk that is fermented in a calabash or plastic container of 5-20 litres to allow spontaneous fermentation at ambient temperatures. After about two days of incubation, a relatively firm, slightly sour, non-alcoholic product is formed that is consumed at home and sold at local markets as an energising and refreshing beverage. It is also consumed with the staple maize-meal thick porridge (*Nshima*). Mabisi has a perceived shelf life of up to 10 days at ambient temperatures. Producers of Mabisi are almost exclusively women, who process for their household and also sell the product at local markets, generating a livelihood for themselves and their families. Men and women, as well as children from a very young age, consume it almost daily in rural areas. Production is in rural areas; at present the product fails to reach larger urban centres and urban consumers. To upscale production from household level to SME level both technological and business development advances are needed. Products based on raw milk are currently not allowed for formal sales, however, previous work has shown that Mabisi is safe for consumption due to its low pH. Other work has shown that health benefits exist through the modulation of gut microbiota towards a healthier composition after exposure to microbial communities from Mabisi.



BOX 2: Cereal-based fermented food from Benin: Akpan

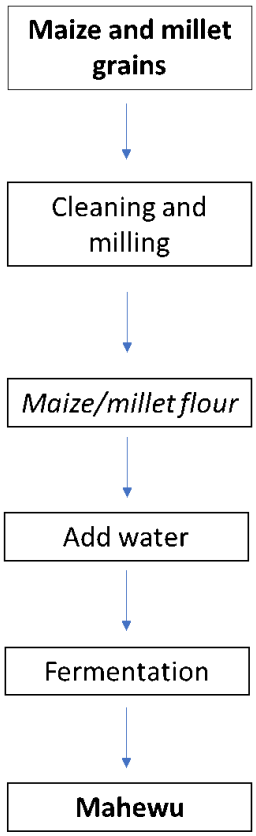
Akpan is a traditional Beninese non-alcoholic fermented cereal-based beverage, locally also known as a vegetable yoghurt. It is made from fermented cereal (ogi) where depending on the taste of the consumer, milk and sugar are added to taste at the end of fermentation. The product is consumed in urban as well as rural areas in the country. The product has received already substantial attention from researchers who have defined detailed protocols for traditional processing (Sacca et al., 2012). Different types of Akpan exist due to slight variations in processing and in the types of cereal used. A recent study on sensory profiling indicated that the consumer preferences differed for the different Akpan variants which are around (Akissoé et al, 2015). Akpan originates from rural areas and is now also produced in larger cities, close to poor urban consumers who are the main consumers at the moment. The raw materials are relatively easy to obtain in the cities. Research has been done in the past 15 years on the product by the University of Abomey-Calavi and others as part of the AFTER project (EU-FP7), labelling and standard processing have been suggested. Some small-scale processors have now developed modern packaging and labelling. Production is a purely women's activity. Sales and related activities do sometimes involve men. A technological hurdle is to generate a version with an extended shelf life. Implementing the mechanisation of some steps in processing is also needed to upscale in urban areas. Given the small-scale production, these machines are not affordable to individual processors. Some sort of associations between processors could be formed to facilitate upscaling. This would also give them a voice towards supermarkets and other outlets to sell their products.



Two variants of Akpan, each made with different fermentable substrates. Picture from: Sacca, Akissoe, Dalode, Anihouvi, Hounhouigan and Mestres. 2012. Food Chain 2: 207-220. Poster FP7 245-025 AFTER project.

BOX 3: Mixed cereal-based fermented beverage from Zimbabwe: Mahewu

Mahewu is a mixed maize/sorghum cereal-based fermented non-alcoholic beverage. Many versions of such cereal-based fermented beverages exist in southern Africa and Mahewu from Zimbabwe is usually produced with maize as the main fermentable substrate. Processing of Mahewu has been researched and microbial profiles and suggestions for processing optimization have been suggested. Lactic acid bacteria dominates the microbial community involved in the spontaneous fermentation of Mahewu. Besides household level production, commercial variants of Mahewu are also being produced and becoming quite well known in Zimbabwe, but these products are often highly simplified and lack a fermentation step or do not contain complex microbial starters, which does not match consumer's expectations of a traditional product. Obviously, the latter products are often consumed in urban regions while homemade Mahewu is still available in rural Zimbabwe. In general, Mahewu from Zimbabwe is low in nutrients and the use of provitamin A (β-carotene) enriched maize (also known as orange maize) as a fermentable substrate has been suggested as a means to promote the nutritional content of the beverage. Traditional Mahewu is promoted for school-feeding programmes in rural areas. The production of traditional Mahewu takes place in rural areas and could be done as well in urban areas close to focal consumers.



3.1 Opportunities for value chain development, linking supply and demand

Upscaling of processing requires value chain development which should focus on connecting the desires and needs of consumers to the capabilities and aspirations of the processors while considering the availability of raw materials, institutional context and aspects of logistics that affect the value chain. Apart from product availability, important aspects for consumers when choosing a product include taste and other sensory properties, food safety and formal standards, packaging, and convenience. Consumer preference for taste may be determined by what traditional foods these consumers have been exposed to. Regional differences exist for traditional processing resulting in differences in taste preference. When choosing which specific traditional process to upscale for a given product, these differences in taste preference should be

taken into account and the processing favoured by target consumers should be chosen. For instance, in the case of Mabisi, we have found that within Zambia seven types of Mabisi exist with slightly different processing techniques, resulting in products with different properties (Moonga et al., 2019, 2020). Of these, the so-called Tonga-type processing of Mabisi has the highest appeal to urban consumers in Lusaka and some other large towns. More rural communities in the Western part of the country would prefer the so-called Barotse-type of processing to be used. When urban consumers were interviewed on their perceptions of food safety of traditional fermented foods including Mabisi and Mahewu, half of all consumers (n=172) interviewed perceived the traditional product as safer compared to the commercial alternative (51 per cent). The majority (60 per cent) associated no risks to the consumption of the traditional product (van de Ven, 2018). The consumers who did express safety concerns expressed that formal standards could mitigate these concerns. Packaging in containers similar to industrialized products promotes trust in the products by consumers (van de Ven 2019).

The technology used for upscaled processing should be within reach of current small-scale processors. Household level traditional processors currently produce typical volumes of up to 20 litres per day for Mabisi and Mahewu and up to 50 litres for Akpan. Upscaling to SME level (500 litres per day or more) requires larger equipment than current household level processing. For some product categories, processors have joined forces, for instance in collecting milk at cooperatives and milk collection centres. The resulting abundance of raw materials allows technologies of processing to develop and upscale to SMEs, using industrial style equipment and standard processing techniques and protocols to meet safety and consumer standards. Mabisi could be upscaled at milk collection centres by groups of current small-scale processors. For Mahewu and Akpan, some form of organization among processors is also needed to facilitate SME-level processing technology.

The institutional context mainly applies to formal standards. For most traditional foods that are uniquely sold at informal markets, no formal standards exist. These standards include an assessment of food safety and will set critical parameters of processing to meet food safety standards (van der Zon, 2019). Lack of formal standards is a concern for some potential consumers, mainly consumers from middle and upper classes, and impedes sales at formal outlets such as supermarkets. This is also true for our three focal products. Standards bureaus in Zambia, Zimbabwe and Benin have initiated formal procedures to set standards for these traditional foods by adjusting international standards of similar products to specific properties of the traditional foods. For instance, the Zambia Bureau of Standards has used the EU standard of raw milk fermented foods to start to define what formal standards for traditional Mabisi from raw milk should look like (van der Zon 2019). While these standards may prescribe certain processing parameters for processors to adhere to, such as a minimum time of fermentation and standards for pH levels, these requirements are likely within reach for current local processors.

Logistics within the value chain also require special attention. Some products, such as Mabisi, are uniquely processed in rural areas where the raw materials (fresh milk) are available, some are produced both in rural and urban areas, such as Mahewu, and some mostly in urban areas. In order to reach large groups of urban consumers, the logistics of transportation of either the final product or the raw ingredients needs to be taken into account. In the case of Mabisi, the transformation of raw milk into the product prolongs the shelf life from one day (fresh milk) to up to seven days without refrigeration, which facilitates these logistics – especially compared to the perishable raw material it is derived from. Mahewu and Akpan have a similar shelf life as Mabisi. Still, this short shelf life requires effective and fast logistics to reach (in)formal sales outlets in urban areas, which may be a challenge. For Mahewu and Akpan, the raw materials (dry cereal) have a longer shelf life than the final product. In these cases, the logistics of transport of raw materials from rural areas where these are cultivated are easier than transporting the final product. Thus, for Akpan and Mahewu processing in urban areas would make sense from a logistics point of view. At the same time, processing in rural areas could still be preferred since many current processors are in rural areas and the shelf life of final products is long enough to allow for transport and distribution over greater distances.

3.2 Impact of industrialized variants of traditional fermented foods on the value chain of these traditional foods

The presence of industrially processed foods that are similar to traditional foods provides both opportunities and constraints to the upscaling of traditional processing. For several years, large commercial producers have been making products inspired by traditional foods, although according to many consumers, these commercial variants are inferior to the traditional product. For instance, in Zambia a commercial product called lacto-Mabisi exists that is inspired by the traditional fermented food Mabisi. Lacto-Mabisi is made of pasteurized milk and processing is standardized. To start the commercial fermentation process, a mix of two bacterial strains normally used to make cream cheese is added. Traditional Mabisi is fermented by a microbial community of at least 10 strains. This results in a very flat aroma in lacto-Mabisi compared to traditional Mabisi and the need for refrigeration in the case of lacto-Mabisi. Interviews in large urban areas have shown that around 80 per cent of consumers would prefer the traditional Mabisi, yet they buy lacto-Mabisi since the traditional variant is unavailable (van de Ven, 2019). In Zimbabwe, Mahewu has been commercialized with processing through the addition of enzymes to break down starch and one bacterial strain to add artificial aroma. Industrial Mahewu requires refrigeration. This contrasts with traditional Mahewu, for which fermentation is dominated by over 10 bacterial species. Similar to Mabisi, consumers have indicated a preference for the traditional version of Mahewu if available. Akpan has not been commercialized at an industrial scale.

The presence of industrial variants has several advantages for the traditional products and their potential for upscaling. Through the industrial variants, consumers remain connected to the type of product. Consumers do value the certified safety of industrial processing, demonstrating that the same would apply to traditional foods once these comply with formal safety standards. The industrial products can also inform what market price upscaled traditional foods could be sold at, showing that considerable profit could be made by upscaling traditional processing (see section below).

3.3 Opportunities for the enhancement of functional properties (shelf life, food safety, nutritional value and health benefits)

Traditional fermented foods have unique functional properties over other processed foods, mainly in their food safety attributes and enhanced nutritional value. These properties rely on the presence of a diverse microbial community that is responsible for fermentation. The diverse nature of the microbial community blocks the invasion of pathogenic bacteria and adds nutritional value. Furthermore, the diverse microbial community has been shown to promote the health of its consumers by shifting the balance in the gut microbiota to a healthier composition and by stimulating the human immune system. It is of key importance that these beneficial functional properties are preserved when upscaling processing. This can be achieved by ensuring that fermentation is achieved by a diverse microbial community.

From a technological point of view, it is usually preferred to use a simple microbial community of only one or two strains for fermentation since this will provide more reproducible product properties in processing and is easier to control then when using a more diverse mix of microbes. However, we have shown that once the processing procedures have been standardized, uniform product properties can be achieved by different processors, even when using an undefined mixed of bacteria that contain at least 15 different bacterial species (Moonga et al., 2020). This shows that traditional processing can be upscaled while maintaining the unique functional properties.

Previous work has shown that the three focal products have intrinsic properties of microbial safety. Traditional Mabisi has been shown to be a safe product. Formal experiments using standard protocols by the European Food Safety Authority as well as the Zambia Bureau of standards show that traditional processing reduces the growth to acceptable levels of all relevant pathogens, such as *Salmonella*, *Staphylococcus aureus* and *Listeria monocytogenes*, even when rejected milk is used (van der Zon, 2019). Traditional Mabisi has a shelf life of around one week without refrigeration. Since Mahewu and Akpan have highly similar properties with respect to microbial ecology, we expect similar outcomes at the level of food safety for these foods.

The nutritional impact of the consumption of traditional foods has been demonstrated by a recent study that shows how the addition of traditional fermented Mabisi and Mahewu can improve diets, making them adequate in various micronutrients such as minerals and B-vitamins (Chileshe et al., 2020). For Mabisi, adequacy was also achieved for fat and protein. Figure 5 shows a few examples (Chileshe et al., 2019, 2020).

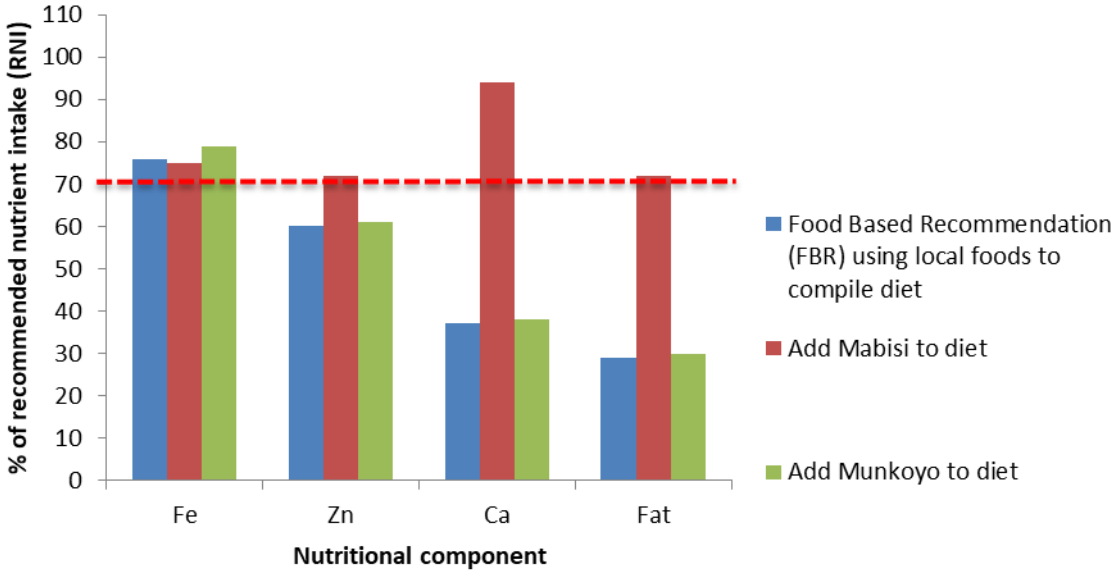


Figure 5: Analysis of the nutritional content of current diets and the potential effect of adding Mabisi and Munkoyo (Munkoyo is highly similar to Mahewu). Children were found to have inadequate intakes for the nutrients Calcium, Iron and Zinc. When diets were adjusted using optimal combinations of locally available foods (Food based recommendations – FBR), fat, calcium and zinc were still problem nutrients as shown in the figure above. Diets were modelled by including Mabisi in the food-based recommendations; here nutrient gaps were closed with all nutrients providing ≥70% of the recommended nutrient intakes (RNI). Figure taken from Chileshe et al., 2019.

In line with findings for other traditional fermented foods (Chileshe, 2020), specific evidence was found that the consumption of Mabisi and Mahewu leads to a shift in the gut microbiota to a healthier metabolism and microbial community composition that has been shown to have health benefits for consumers, including consumers of vulnerable groups.

Marketing and sanitation campaigns could focus on the proven nutritional benefits of consuming traditional fermented foods such as Mabisi, Mahewu and Akpan. The unique properties of acidification, value addition to raw materials by adding vitamins, removing anti-nutritional factors and the blocking of pathogenic bacteria are defined by the ecology of the complex microbial communities that determine the fermentation (Nout, 1994, 2005). Previous research has found significant levels of natural vitamin fortification and the release of micronutrients through the microbial activity in these products (Chileshe et al., 2020). Modelling current diets showed that milk-based products (for example, Mabisi in Zambia and Akpan likewise in Benin, see case study 1 and case study 2) have the potential to optimize the local diet to a level that greatly reduces current levels of malnutrition (Chileshe et al., 2020b; Schoustra et al., 2018). Moreover, in several cases the ingestion of foods with microorganisms has been proven to promote intestinal health, especially of vulnerable groups (Marco et al., 2017; Flint et al., 2012).

3.4 Availability of raw materials

In Southern and Western parts of Zambia, livestock is abundant and has also increased in other parts of the country. This has resulted in a wide availability of raw milk. However, currently around half of the raw milk produced by smallholder farmers goes to waste, amounting to around 100 million litres of raw milk lost annually in Zambia alone (World Bank, 2011; Project Team University of Zambia, 2017). Dairy companies

that purchase raw milk from small dairy farmers through the milk collection centres fail to collect all the raw milk, especially in the afternoon due to logistical obstacles. This leads to particularly high losses of the so-called “evening milk”. On top of this, smallholder farmers milk only around half of their cows they could potentially milk since the additional milk has no outlet. Processing of raw milk into Mabisi can prevent major food losses of raw milk. Unprocessed milk spoils in a couple of hours and is a cause of large post-harvest losses. Local milk processing, for instance into Mabisi, is a potential solution to salvage fresh milk and provide an incentive for higher production. Some milk collection centres have started to informally process their uncollected and rejected yet optically fresh milk into Mabisi, producing around 200 litres of Mabisi per day. This Mabisi is sold to local consumers in nearby small towns and sells out within hours. Experiments have shown that this rejected milk can be used to produce safe Mabisi using traditional processing techniques (van der Zon et al., 2019; van de Ven, 2018). Processing rejected (yet optically fresh) milk into Mabisi is a way to prevent losses of raw milk – an important aspect of food system transformation.

Mahewu and Akpan processing requires maize and sorghum as raw materials. Availability of these cereals is usually not limiting to processors. A concern is the presence of aflatoxins in maize and other cereals, which are highly carcinogenic compounds produced by fungi (*Aspergillus flavus*). In several cases, it has been suggested that processors may use cereal with fungal contamination for processing. Reports have shown that fermentation can eliminate mycotoxins when these are present in the raw materials (Ahlberg et al., 2019; Wacoo et al., 2019).

3.5 Opportunities for monetary value addition

The processing of raw materials into (traditional) fermented foods adds monetary value at two levels: it prevents food losses of perishable raw materials (in the case that raw milk is used) and it increases the commercial value of these same raw materials. Commercial value depends on what consumers are willing to pay. Value addition depends on various aspects, such as the value of the raw materials and the costs of processing, logistics and legislation. Table 1 and Figure 6 show the potential for monetary value addition for our three focal products at various scales/levels of processing. While these metrics of value addition do not take into account batch size and potential economics of scale, the figures show that in principle traditional processing and the SME/cooperative level processing derived from this can be at least as profitable as industrial processing. The potential profit margins are highest for the product made from the most perishable raw material, Mabisi, which is also the most nutritious product in terms of nutritional content per litre. Mabisi processing also requires the fewest processing steps (see box 1).

This underscores that there is high economic potential for Mabisi upscaling (and for fermented milk products in general) of the traditional product through the formalization of processing at milk collection centres where current processors have formed a cooperative. Mabisi processing in itself is a profitable activity. Below is a breakdown of current pricing at informal markets for raw milk and Mabisi, including lacto-Mabisi produced by industrial processors and sold in supermarkets. Per unit of consumption (250 ml of raw milk or Mabisi) the value added is around 150 per cent, which is more than the industrial process which requires pasteurization of raw milk and a cold chain. Costs of raw milk are lower for milk collection centres than for industrial processors since milk collection centres do not incur costs for transport. Currently, Zambian smallholder farmers produce around 200 million litres of milk annually. They only milk approximately half of their cows since there is no market and thus no incentive to milk any more. So, without altering the current agronomic practice of cattle farming by smallholders, milk production could be increased to 400 million litres per day. Currently, smallholders sell around 100 million litres of raw milk to industrial processors. The remaining 100 million litres is not picked up by the commercial company or is rejected at milk collection and mostly discarded. The 100 million litres sell at 4 ZMW per litre (1 EUR = 25 ZMW), worth 400 million annually. If all the 100 million currently remaining milk would be processed, a value of 14 ZMW is added per litre, amounting to 1.4 billion ZMW annually. If all available cows were milked, this profit would double.

Table 1

Potential monetary value addition of transforming raw materials into traditional fermented foods through processes either at the household level, at the level of SME/cooperatives or at the industrial level. Values are based on current local prices at (informal) markets, converted to EUR, per litre.

Product	*Raw materials*	*Processing level*	*Value raw material*	*Processing cost*	*Value (processed) product*	*Value addition*	*Value addition relative to value raw material*	*Batch size processing (litres)*
Mabisi (Zambia)	Raw milk	Household	0.17	0.13	0.87	0.57	325%	10
		SME/cooperative	0.17	0.09	0.87	0.61	350%	200
		Industrial	0.26	0.09	0.87	0.52	200%	2000
Akpan (Benin)	Maize, sorghum	Household	0.11	0.09	0.23	0.04	33%	60
		SME/cooperative	0.12	0.07	0.23	0.04	29%	600
		Industrial	-	-	-	-	-	-
Mahewu (Zimbabwe)	Maize, sorghum	Household	0.17	0.08	0.51	0.25	150%	20
		SME/cooperative	0.17	0.08	0.51	0.25	150%	200
		Industrial	0.25	0.17	0.68	0.25	100%	800

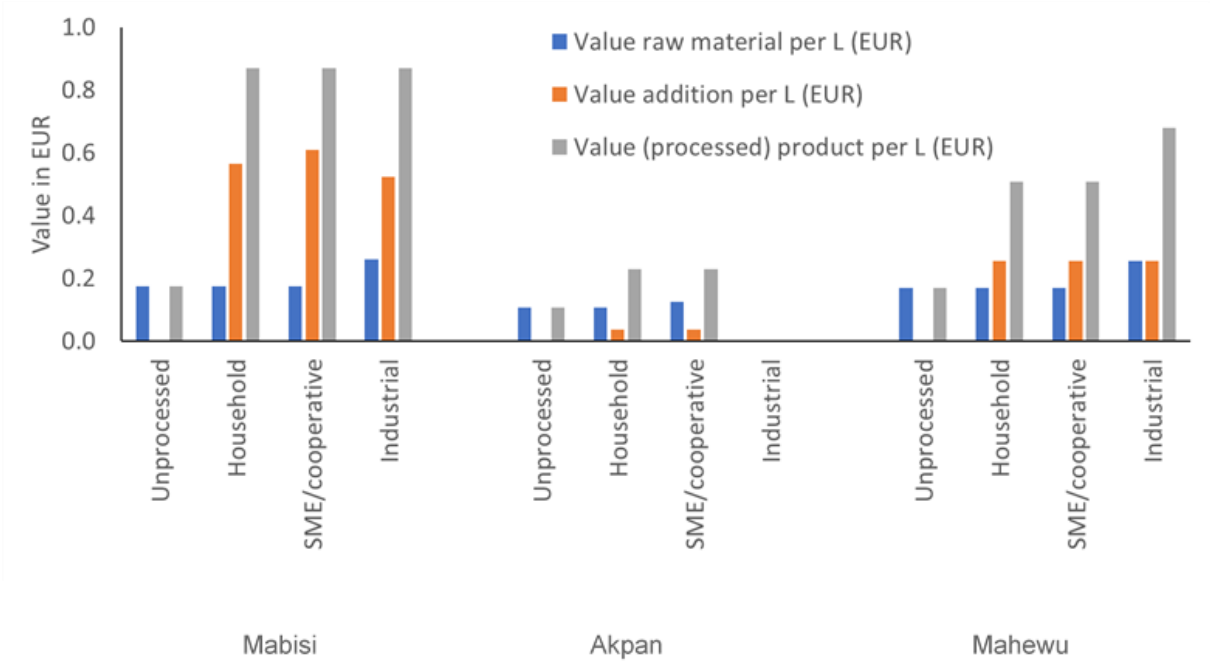


Figure 6: Potential monetary value addition of transforming raw materials into traditional fermented foods Mabisi, Akpan and Mahewu processed at either household level, at the level of SME/cooperative level and at industrial level.

3.6 Current local processors at the centre stage: the route for upscaling traditional fermentation goes through fostering women entrepreneurship

Lifting production and sales from the household level could cause a shift from the predominantly female producers in households to male-based small-scale production systems, potentially putting current producers/sellers out of business. Therefore, we argue that a specific focus on fostering and strengthening women entrepreneurship is needed. Engaging traditional processors when upscaling traditional processing is important for three main reasons. Firstly, they are the owners of the local knowledge on traditional processing. Secondly, empowering local processors is the most sustainable way of long-term development and food and nutrition security. Thirdly, the economic gains are highest when putting small-scale processors at the centre stage. Apart from the fact that upscaling at cooperatives may be (most) profitable (Figure 5), the need for special attention for women entrepreneurs is highlighted by many sources which show that there is a considerable gender gap in entrepreneurial activity worldwide (FAO, 2010, 2015), with significantly more men than women in the process of starting a business or operating new businesses.

Producers and processors of many traditional foods including the ones we focus on are currently mostly women. Optimizing the value chain of their traditional foods generates opportunities for women entrepreneurship (Welter and Smallbone, 2011). A conscious gender approach will lead to more participation in decision making and will improve the social standing of women as entrepreneurs (FAO, 2010). This will lead to higher incomes and performances that contribute to women's social and economic empowerment (FAO 2010, 2011). Women's anecdotes of gaining empowerment and seeking emancipation through entrepreneurship provide examples of women breaking away from male domination in work and society by means of embarking upon self-employment to change their condition of subordination and inspire other women (Anderson and Obeng, 2017; Rindova et al., 2009; Materia and Dentoni, 2020). This is the case of women entrepreneurs in Zambia, who created women-only organizations aspiring to make a social change and providing their support in building the economy of their country. These organizations often offer support to other women who have less opportunities to develop otherwise. Another case is that of women producing local and traditional fermented foods at small-scale in Benin who created their own market by relying on a network of contacts for which they act as connectors and by means of which they create a short

value chain for their product. These women often train others, inspiring them and giving them chances to develop as well (Materia and Dentoni, 2020).

When interventions for integrating gender analysis and market analyses are implemented, this will enhance the reputation and social standing of women entrepreneurs and women's self-determination within the family context and in their self-efficacy as entrepreneurs and businesswomen (FAO, 2010, 2015; Materia and Dentoni, 2020). To overcome these structural gender barriers, a partnership including stakeholders with gender expertise, both at the academic institutions guiding research as well as at practitioner level, is advisable. Gender analysis can pay specific attention to requirements that ensure that young and older women will continue to be the entrepreneurs who benefit from Mabisi, Akpan and Mahewu production and sales through their participation in cooperatives and taking leadership roles. This is particularly important since research demonstrates that when income increases or cooperatives are formed, poor women, especially the very young and elderly, often fall out of the value chain (FAO, 2011). A market assessment might then pay special attention on how to reach resource-poor women consumers and their families and how to support those that are most likely to succeed in the business, at least at first. These kinds of interventions will influence the context in which women operate towards protection against food borne disease combined with the higher social standing of women entrepreneurs and equal opportunities for women and men to achieve personal and community development.

As supporting women in their small-scale businesses is a crucial way to ensure that women are empowered for achieving a transformation, several initiatives have been launched so far globally in the agrifood sector to support women and create a network around them that protects them in their entrepreneurial activities. For example, the *Catalogue for African Women in Agribusiness* is one of the tools created for supporting women in agribusiness by enhancing networking opportunities and exposing them to potential buyers, funders, investors, partners, mentors and policy makers (AUDA-NEPAD, 2019). The *Conference for Women in Agribusiness* is moreover a continental platform within the Gender Climate Change and Agriculture Support Programme (GCCASP) of AUDA-NEPAD that brings together women farmers and entrepreneurs within the agriculture-agribusiness arena from across the continent to share information, ideas, knowledge and best practices through policy dialogue, capacity building (training) for entrepreneurial development, exhibitions of goods processed by women entrepreneurs and peer learning through field visits. In the "Lionesses of Africa" community, there are a number of women entrepreneurs who are playing their role in Africa's growing agribusiness story by building successful businesses that harness the potential of the raw materials found on the continent by transforming them into products that people want to buy.

Beyond the local and village level, the market potential of fermented products needs to contend with several prerequisites, including larger facilities for production, more ad hoc equipment, consistency and reliability in quality control, labelling, licensing, labour and so forth (FAO, 2011). These examples of initiatives prove that the institutional environment, contacts with relevant stakeholders, and having proper connections in the value chain, make small enterprises more resilient and because of this, more scalable. In addition, it makes them a more reliable source of income for a vulnerable group of people (women entrepreneurs) that often support many dependents, people that may have few alternative sources of income. To be able to upscale their processing, small-scale processors will have to form associations that allow them to gain more access to the capital required for equipment and other assets and to influence their institutional environment.

Developing and upscaling the value chain of traditional and culturally embedded foods that support the women producing them will have a positive impact on sustainable smallholder-based food systems in low- and middle-income countries. An important challenge for the majority of developing country producers is how to enter value chains and improve access to new markets. There is the need to provide understanding of how producers can become more efficient and collaborate with parties in (existing or new) value chains that are able to capture new market opportunities; how value chains, can optimally use the business environment in which actors operate; what opportunities are available to upgrade and which parties are most suited to facilitate this process; and how to make value chains more gender sensitive.

4. From farm to market: a possible agenda for policy?

In Africa and around the world many traditional fermented foods exist that could be promoted to support entrepreneurship in local processors, build value chains and promote food and nutrition security for producers and consumers. In this way, the “hidden middle” between primary processing and improved and processed foods can be bridged (Reardon and Liverpool-Tasie, 2020). Policy interventions should firstly address and support the needs of local (women) entrepreneurs, to address their needs to improve the enabling environment for gender-sensitive value chains. Policy should focus on the technologies, institutions and other innovations that improve women’s empowerment and agricultural outcomes for their families. Value chain interventions should be planned and implemented to make sure that men and women can benefit. Further, policy should enable legislature to formalize and put standards in place to allow traditional fermented foods on the formal market. This will open up a wider range of consumers and will give self-esteem to local processors acknowledging that they provide a product that adheres to food safety standards.

To be more concrete, our contribution suggests the need for actions in the direction of: (1) standardization and formalization of processing, and upscaling of sustainable and profitable production to meet demand; (2) support for the producers to organize themselves (e.g. cooperatives) and provide infrastructure (e.g. storage facilities) and partnerships to create market linkages; (3) support the acts of balancing that women are currently doing embedded in the community and family they live in; (4) include fermented products in nutrition feeding schemes and promotions. For this to have an impact, it is recommended that: (a) sensitization at community level is needed on the benefits of traditional products; (b) the focus should be on building women’s awareness of their own current limits and potential roles in transforming the business and society that surrounds them; (c) mindset change is crucial to create awareness communication (local language) as needed; (d) increase awareness of entrepreneurship as bottom up agency by women to address the root causes of food insecurity.

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