Food Control 145 (2023) 109393

Contents lists available at ScienceDirect

Food Control

journal homepage: www.elsevier.com/locate/foodcont

African traditional foods and sustainable food security

O. Charles Aworh

Department of Food Technology, University of Ibadan, Nigeria

ARTICLE INFO

Keywords:
African traditional foods
Upgrading traditional foods
Food safety
Lactic acid fermentation
Sun-drying
Small-scale food processing

ABSTRACT

Dietary diversity is key to sustainable food security and part of Africa's rich biodiversity heritage are hundreds of lesser-known indigenous crops and wild food plants that are important components of African traditional diets. African traditional foods and African food processing techniques are part of the rich cultural heritage of the people. Fermentation and sun-drying are two of the most important African traditional food processing techniques used for the production of a wide range of processed food products and for low-cost food preservation under non-refrigeration conditions. Lactic acid fermentation is used for the production of a variety of African traditional foods from plant and animal sources that are safe, nutritious and contribute to food security. Some of the organisms are probiotics that offer distinct health benefits. However, African traditional foods are still largely prepared in the home and the unregulated informal food sector. Their production is characterized by slow, manual operations; the processes are not standardized and the quality of the products are variable and often poor. There are serious safety concerns with many African traditional foods and beverages largely on account of the unhygienic conditions under which they are prepared, the quality of the raw materials and the packaging. Another safety concern with regards to African traditional fermented foods is foodborne antimicrobial resistance (AMR) in bacteria that reduces the options for treating human and animal diseases. Some successes have been recorded in reducing the drudgery associated with African traditional food processing, carried out mainly by women, and increasing the capacity, efficiency and safety of the processes and the quality of the products through the introduction of small machines for small-scale industrial production. Solar drying eliminates the problem of poor quality and unsafe products associated with the traditional open air, shallow layer sun-drying. Even though considerable amount of research has been carried out on upgrading African traditional foods, they remain largely at the bench stage. The establishment of zonal or regional food pilot plants will facilitate the commercialization of research findings from African universities and research institutes, improve traditional foods and processes, and promote sustainable food security.

1. Introduction

Ensuring food security by providing access to food of the right quantity and quality to every child and adult for a productive and healthy life for the over 1.4 billion Africans is one of the biggest challenges of the 21st century for Africa, a continent characterized by high population growth rate of up to 3% per annum (in some African countries), inefficient food production systems, weak supply chains and pervasive poverty and food insecurity (Aworh, 2015, 2020; Canagarajah & Thomas, 2001; Oshewolo, 2010). There is a high prevalence of undernutrition in Africa and most African countries are unlikely to meet the Sustainable Development Goal of ending hunger and achieving food and nutrition security by 2030 (UNICEF/WHO/World Bank, 2017). In many parts of sub-Saharan Africa (SSA), nutritional diseases such as protein-energy malnutrition in children and micronutrient deficiencies (the hidden hunger), especially vitamin A, iodine, iron and zinc deficiencies, are still prevalent exerting devastating effects on productivity, intellectual development and maternal and infant health (Aworh, 2015).

Prime determinants of national food security include the availability, stability and accessibility of foods. Food availability is determined primarily by the level of food production and importation. Seasonal food shortages and high post-harvest losses are major constraints to food stability and the purchasing power of the people is a prime determinant of food accessibility (Aworh, 2010). The primary causes of food insecurity in Africa are inadequate food production, high post-harvest food losses and high level of poverty (Aworh, 2010). Agricultural production is very inefficient in Africa and productivity (crop yield per hectare and output per unit animal) is very low compared to developed countries. Over 90% of agricultural production in most parts of SSA is by small,

E-mail addresses: oguguaaworh@gmail.com, ocawo51@yahoo.co.uk, charles.aworh@mail.ui.edu.ng.

https://doi.org/10.1016/j.foodcont.2022.109393
Received 2 May 2022; Received in revised form 7 September 2022; Accepted 18 September 2022
Available online 3 October 2022

resource-poor farmers, often with holdings of less than 1 ha and many African countries rely heavily on food importation to feed the people (Aworh, 2015). SSA spent $43 billion on food importation in 2019 with Nigeria, Angola, the Democratic Republic of Congo and Somalia accounting for most of SSA's food imports (Fox & Jayne, 2020). Wheat, rice, sugar, fish, milk/dairy products and vegetable oil are the major foods imported by Nigeria (Vaughan et al., 2014). Poverty is widespread in Africa and it is estimated that about 45% of the people of Africa live below the poverty line; the highest in the world (Anyanwu & Erhijakpor, 2010). Other factors responsible for food insecurity in Africa are high unemployment, poor health facilities, low level of nutrition education, cultural factors and taboos that reduce access to food and government policy failures (Aworh, 2010). Wars, civil unrests, political instability and natural disasters such as droughts and floods that affect agricultural production leading to crop failures and famines, displacement of populations and increased poverty aggravate food insecurity in Africa (Smith et al., 2000).

Dietary diversity is crucial to food security and sustainable food security cannot be realized by dependence on a few crops such as rice, maize, wheat and soybeans that account for a major part of global food supply. Part of Africa's rich biodiversity heritage are numerous lesser-known indigenous crops and wild food plants that are important components of African traditional diets. Referred to as orphaned or lost crops, these crops and wild food plants that include cereals, legumes, roots and tubers, fruits and vegetables have been largely neglected by the mainstream of international science and receive little research and extension attention (National Research Council, 1996; 2006; Aworh, 2015, 2018). Yet, these indigenous crops and wild food plants play critical roles in food and nutrition security, especially in rural communities, on account of their availability and affordability. They thrive with little care and without the use of agricultural inputs such as fertilizers, herbicides and pesticides that resource-poor, smallholder farmers cannot afford. These indigenous crops and wild food plants are invariably more resistant to pests and diseases, drought and other unfavorable growing conditions than crops introduced to Africa and are available during the so-called hungry season when other more common sources of food are out of season (Aworh, 2015, 2018).

Prominent among Africa's indigenous crops and wild food plants that are important components of African traditional diets are hundreds of traditional fruits and vegetables, including forest resources, that are potent weapons against dietary deficiencies because they are often the cheapest sources of essential nutrients such as ascorbic acid, provitamin A carotenoids, folic acid and many minerals including calcium, iron and zinc (Stadlmayr et al., 2012; Aworh, 2014, 2015, 2018). Some of these lesser-known African traditional fruits and vegetables are much richer in vitamins and minerals than the more expensive conventional fruits and vegetables of international trade introduced to Africa. For example, baobab (*Adansonia digitata*) fruit pulp is reported to have vitamin C content of 162–499 mg/100g with marked variation from tree to tree (Sidibe et al., 1998). *Moringa oleifera* (164 mg/100 g) and *Telfairia occidentalis* (129 mg/100 g) are amongst African traditional vegetables that have much higher levels of vitamin C than oranges with 41–70 mg/100 g (Aworh, 2018). In addition, African traditional leafy vegetables are rich in fiber and nutraceuticals including polyphenols, tannins, flavonoids and flavonols that exert demonstrable antioxidant, free radical scavenging and enzyme inhibition activities that confer health-promoting benefits (Aworh, 2014, 2015; Oboh et al., 2008; Uusiku et al., 2010). The dry nuts and seeds of many African indigenous fruits and vegetables may be rich in protein, carbohydrates and fat and contribute significantly to protein and energy intakes (Aworh, 2014). African traditional vegetables together with a wide variety of wild food plants are used as part of the main dishes in African traditional diets. They may also be used as condiments in the preparation of soups and sauces served with starchy staple foods made from roots, tubers and grains (Aworh, 2014).

African traditional fruits and vegetables play important roles in traditional medicine. Many of them have antimicrobial and anti-helminthic properties and are used for the management of a wide variety of ailments including stomach ache, diarrhea, dysentery, anemia, diabetes, hemorrhoids, cough, malaria, intestinal worms and other parasites, skin, eye, mouth, sexual and other infections (Chothani & Vaghasiya, 2011; Farombi, 2003; Njume et al., 2014; Opande et al., 2017). Many of Africa's traditional leafy vegetables are functional foods that reduce the risk to several diet-related, non-communicable diseases such as obesity, diabetes, hypertension and cardiovascular diseases (Aworh, 2018). Changing food consumption patterns in Africa, due largely to urbanization, in which African traditional diets of the rural areas that are rich in fresh fruits and vegetables, legumes, cereals, roots and tubers have been replaced by energy-dense "western diets" of the urban areas characterized by high intakes of fat, meat, especially fatty meat, sugar and salt with low intake of fiber, coupled with sedentary lifestyles, contribute to the increase in the incidence of diet-related, non-communicable diseases in Africa (Aworh, 2010; Naicker et al., 2015; Stamoulis et al., 2004). Africa now faces the paradox of the double burden of the adverse health consequences of undernutrition, obesity and over-nutrition in the midst of pervasive poverty, further stressing the fragile health care system (Kalipeni et al., 2018, pp. 3–9). The important roles that Africa's traditional leafy vegetables play in food security and wellness are now being recognized and some of them have been referred to as super vegetables on account of their unique qualities including high nutritional value and chemotherapeutic and health-promoting properties (Aworh, 2018; Cernansky, 2015).

The nutritional and nutraceutical properties of different groups of African traditional foods including a wide variety of fruits and vegetables, roots and tubers such as African wild yam species (*Dioscorea* spp) and African potato (*Plectranthus esculentus*); African mushrooms such as *Termitomyces mammiformis* and *Lactarius triviralis*; legumes such as cowpea (*Vigna unguiculata*) and Bambara groundnut (*Vigna subterranea*); cereals such as sorghum (*Sorghum bicolor*) and pearl millet (*Pennisetum glaucum*); oilseeds such as sesame and African oil bean (*Pentaclethra macrophylla*); and edible insects of the orders *Lepidoptera, Coleoptera, Hymenoptera, Orthoptera, Hemiptera, Isoptera and Diptera* have been described, and their potential contributions to the sustenance of nutrition and health discussed (Muyonga et al., 2018, pp. 229–244). Even though African traditional food processing techniques have several inherent strengths, African traditional foods are often associated with food-borne illnesses especially those due to pathogens including bacteria and viruses as well as parasites that cause diarrhea and other gastro-intestinal diseases, mycotoxins, chemical adulteration and naturally occurring toxicants such as cyanide in cassava (Aworh, 2020; Oguntoyinbo, 2014; WHO, 2015). There are guidelines developed by the Codex Regional Committee for Africa for preventing food hazards and protecting consumers from food-borne illnesses. The use of potable water, to eliminate water-borne infections, the adoption of good agricultural practices, good hygienic practices, good manufacturing processes and Hazard Analysis Critical Control Points are among measures to improve the quality and safety of African traditional foods (Anyogu et al., 2021; Aworh, 2020; DeWaal et al., 2022; Okoruwa et al., 2022). This paper highlights the critical role that African traditional foods play in food and nutrition security, the strength and weaknesses of African traditional food processing technologies, and the need to upgrade them through innovation, research and development for sustainable food security in Africa.

2. African traditional food processing: an art

African traditional foods and African traditional food processing techniques are part of the rich cultural heritage of the people. They have been in existence since ancient times, dating back thousands of years. Unlike electronics, computers, digital technology and modern and emerging food processing technologies such as canning, high pressure processing, pulsed electric fields, ultrasound and 3-D printing, African traditional food processing techniques far preceded any scientific understanding of their inherent nature, strength and weaknesses (Aworh, 2008). They are an art, useful skills acquired empirically, based on observation and experience over centuries, rather than theory, and passed on from parent to child over generations. It is just in the last few decades that some understanding of the science behind some of Africa's traditional food processing techniques such as detoxification of cassava in *garri* processing, lactic acid fermentation of a variety of African fermented foods and beverages, and coagulation of milk in West African cheese-making have emerged through research (Aworh, 2008, 2010). Even though African traditional food processing techniques constitute a vital body of indigenous knowledge, they are, regrettably, often undervalued. There is no doubt that a considerable part of this body of indigenous knowledge and many African traditional processed foods have been lost over the years. The African traditional food processing techniques that have survived have stood the test of time and are more relevant to the present economic, social and technological realities of Africa (Aworh, 2008). Fermentation and sun-drying are two of the most important traditional food processing techniques in Africa used for the production of a wide range of processed food products and for low-cost food preservation under non-refrigeration conditions. The objectives and characteristics of some of Africa's traditional food processing techniques including preliminary/post-harvest operations such threshing, winnowing, dehulling and peeling; dry milling and wet milling; heat processing such as roasting, cooking, parboiling and blanching; sun-drying, smoke drying and fermentation have been described (Aworh, 2008).

3. Sun-drying

Sun-drying which involves the use of sunlight, either direct or diffuse, to remove moisture from a product is one of the earliest methods of food preservation that is still widely practiced in many parts of the world. Even though modern techniques of food dehydration (mechanical forced-air drying methods such as cabinet, tunnel, fluidized-bed and spray drying, drum drying, microwave drying, vacuum drying and freeze drying) have largely replaced traditional sun-drying in developed economies, traditional sun-drying still remains one of the most important methods of food preservation in Africa (Komiloglu et al., 2016; Sagar & Suresh, 2010). Even though sun-drying is one of the simplest and most economical methods of food preservation in tropical Africa, it has several limitations (Aworh, 2014). It is dependent on the weather and can be used successfully only in regions with relatively high temperatures, low relative humidities and freedom from rainfall during the dry season. Sun-drying requires considerable space and is labor-intensive. Scrupulous care is needed to ensure even drying and avoid over drying and the products may be infested by insects or contaminated by sand, wind-borne dirt, animal feces and other debris.

3.1. Dried fruits and vegetables

African traditional fruits and vegetables suffer high post-harvest losses because of poor post-harvest handling practices, including inefficient distribution and marketing, and lack of storage facilities, reducing their contribution to food security (Aworh, 2020). These highly perishable commodities are high in moisture content, generally 65–95%, and the high moisture content promotes biochemical and physiological changes as well as microbial activities that limit shelf life, especially at high tropical ambient temperatures (Aworh, 2014). They are commonly preserved in Africa by drying in the sun. Traditional sun-dried okra, tomatoes, peppers (capsicums), onions, spices, leafy vegetables and other products are popular in Africa (Aworh, 2014). Drying reduces the weight and volume of fresh fruits and vegetables resulting in substantial savings in handling, storage and distribution costs (Komiloglu et al., 2016; Sagar & Suresh, 2010). It also inhibits biochemical and physiological changes and microbial activities, eliminating the need for costly refrigeration during transportation and storage. These are important advantages that make drying an appropriate technology for the preservation of perishable produce in Africa (Aworh, 2014). However, the traditional sun drying technique in which fruit and vegetable pieces are dried in shallow layers in the open on any available surface, though highly economical, results in products that are poor in nutritional, sensory and microbiological qualities. Product yield is poor because of losses in sugars and other food constituents by respiration and fermentation during the long drying period required (Aworh, 2014). Enzymatic and non-enzymatic changes in chemical composition as well as contamination by microorganisms and insects, and exposure to wind-borne dirt, livestock feces and other contaminants impair product quality. Nutrient losses may be considerable including vitamins, especially vitamin C and pro-vitamin A carotenoids (Komiloglu et al., 2016; Oboh & Akindahunsi, 2004). However, there is the need for further studies on the effects of sun-drying on antioxidants in fruits and vegetables (Komiloglu et al., 2016).

3.2. Traditional processed meat and fish products

A diet that contains a variety of foods from the different food classes is best for sustainable food and nutrition security. Animal proteins are the best sources of essential amino acids, but their intake is very low in many parts of Africa where rural diets are based predominantly on cereals, legumes and starchy roots and tubers with limited consumption of meat, poultry and fish (Schonfeldt & Hall, 2012). Sun-drying is closely linked with smoking, salting and curing, and they constitute the oldest methods of meat preservation that are still widely practiced in different parts of the world (Teixeira et al., 2020). Traditional processed meat products like *suya* or *tsire* or *balangu*, *kilishi, banda* or *kundi*, *ndariko* and *jirge* are important components of the diets in many West African countries including Nigeria, Chad, Niger and Mali where they are valuable sources of animal protein (Aworh, 2008). *Suya* is a very popular ready-to-eat boneless, whole-tissue, roasted, spiced, salted meat product usually made from slices/strips of beef, mutton, chevon or camel meat (Farouk & Bekhit, 2012). *Kilishi*, like *suya*, is also made by roasting spiced, salted slices/strips of meat (usually beef), but in this case, roasting is preceded by sun-drying (Farouk & Bekhit, 2012; Ogunsola & Omojola, 2008). *Banda* is a stone-hard, dark-colored, poor quality salted, dried meat product made from pre-cooked chunks of cheap, low-quality meat by smoking/kiln drying or sun-drying. Meat from donkeys, asses, horses, camel, buffalo and other types of livestock and wild life are used for *banda* production (Aworh, 2008). *Ndariko* and *jirge* are made by sun-drying meat strips; but in the case of *jirge*, sun-drying is preceded by fermentation (Aworh, 2008). Traditional processed meats are also important components of the diet in other parts of Africa. *Biltong*, a Southern African cured and air dried meat product made from all types of meat from livestock and wild life, is found in many parts of the world (Farouk & Bekhit, 2012). Historical origin, preparation methods, quality characteristics, eating practices and socio-cultural aspects of 32 of some of the best known ethnic meat products from five North African countries (Morocco, Algeria, Tunisia, Libya and Egypt) have been discussed (Gagaoua & Boudechicha, 2018). The products classified into five groups including salted and or marinated; dried, non-fermented; fermented, semidry/dried; smoked; cooked and or candied; are diverse in terms of their methods of preparation and preservation, the ingredients used, and organoleptic and other quality characteristics (Gagaoua & Boudechicha, 2018).

Fish such as African catfish (*Clarias gariepinus*) are also commonly preserved by sun-drying, smoking, salting and curing, especially in the coastal areas of Africa (Aworh et al., 2002; Ihenacho et al., 2017). The safety of African traditional processed meat and fish products is a major source of concern given the unhygienic conditions under which they are processed and the many opportunities for product contamination during preparation (Aworh, 2008; Farouk & Bekhit, 2012). Insect infestation, particularly *Dermestes maculatus*, is a common problem in dried fish products and the spices used for processed meats are potential sources of microbial contamination, with high microbial populations, including coliforms, and the presence of pathogenic bacteria reported in retail *suya* (Aworh, 2008; Aworh et al., 2002).

4. Traditional fermentations

Fermentation is one of the oldest techniques of food preservation and remains one of the most important food processing technologies in Africa. In food fermentations, microorganisms and enzymes transform agricultural raw materials into value-added food products with distinct quality attributes that are quite different from the original raw material. Traditional fermentations make such plant items as African locust bean (*Parkia biglobosa*) and African oil bean (*P. macrophylla*) that are inedible in their unfermented state into highly desirable foods through extensive hydrolysis of their indigestible components and development of desirable textural, flavor and other organoleptic quality attributes (Aworh, 2010). Fermentation may lead to significant improvement in the nutritive quality of foods by increasing the digestibility of proteins through hydrolysis of proteins to amino acids, increasing bioavailability of minerals such as calcium, phosphorus, zinc and iron through hydrolysis of complexing agents such as phytate and oxalate, and increasing nutrient levels, especially B-vitamins, through microbial synthesis (Aworh, 2010). Fermentation improves food safety by the elimination of naturally occurring food toxicants. In West Africa, without the benefits of modern science, a process for detoxifying potentially toxic cassava roots that may contain up to 500 mg HCN/kg of root, and in unusual cases more than 1000 mg/kg, was developed several centuries ago, and passed on from generation to generation (Aworh, 2008). The product known as *garri* is one of the most important fermented foods in West Africa.

4.1. Lactic acid fermented food products

The most important traditional African food fermentation is lactic acid fermentation. Lactic acid bacteria (LAB) are a group of Gram-positive bacteria in the order *Lactobacillales* with the families Lactobacillaceae and *Leuconostococcaceae* comprising the most important non-pathogenic microorganisms used in food fermentations (Ganzle, 2015). LAB are commonly simply classified as homofermentative (homolactis) and heterofermentative (heterolactis). Homofermentative LAB, including members of the genera *Pediococcus*, *Streptococcus*, *Lactococcus* and *Vagococcus*, and some lactobacilli, produce lactic acid as the sole or main product of carbohydrate metabolism using the glycolytic pathway of metabolism. Heterofermentative LAB, mainly of the genera *Leuconostoc*, *Oenococcus, Weissella*, *Carnobacterium, Lactosphaera*, and some lactobacilli, produce lactic acid, acetic acid and ethanol from carbohydrate metabolism using the phosphoketolase metabolic pathway (Ganzle, 2015; Jay, 2000). The products of lactic acid fermentation impart desirable flavour, colour and other sensory quality attributes to fermented foods (Aworh, 2010; Ganzle, 2015).

LAB (largely of the genera *Lactobacillus, Lactococcus, Leuconostoc, Streptococcus, Weissella* and *Enterococcus*), *Bacillus* and yeasts (*Saccharomyces, Schizosaccharomyces, Rhodotorula, Candida, Debaromyces, Torulopsis, Trichosporon*) are the dominant and most frequently isolated microorganisms in African traditional food fermentations (Anyogu et al., 2021; Aworh, 2010). These microorganisms occur naturally in agricultural raw materials, the soil and the environment. Various publications including recent reviews have highlighted the wide spectrum of lactic acid fermented African traditional foods produced in different parts of Africa that contribute to sustainable food security (Anyogu et al., 2021; Aworh, 2014; Mokoena et al., 2016). Common lactic acid indigenous fermented foods from plant sources in Africa include: (i) a variety of dietary staples from starchy roots and tubers predominantly cassava such as *garri* (Nigeria), *agbelima* (Ghana), *attieke* (Cote D'Ivoire), *Lafun* (West Africa), *fufu* (West Africa), *Chikwangue* (Central Africa), and *elubo* (Nigeria) made from yam; (ii) porridges/puddings/dough made from maize, millet, sorghum and other cereals such as *ogi* or *akamu*, *eko* or *agidi* (Nigeria), *koko, kenkey* (Ghana), *mawe* (Benin and Togo), *degue* (Burkina Faso), *fura* (West Africa), *togwa* (Tanzania), *poto poto* (DR Congo), *hussuwa* (Sudan) and *injera* (Ethiopia); (iii) alcoholic beverages including palm wine (West Africa) made from the sap of palm tree species, *burukutu/pito/otika* (Nigeria), *shekete* (Nigeria), *tchoukoutou* (Benin), *busaa* (Kenya), *borde* (Ethiopia) and *sesotho* (South Africa) made from cereals, and *agadagidi* (Nigeria) made from plantain and banana; (iv) non-alcoholic beverages made from cereals such as gowe (Benin), *kunun-zaki* (Nigeria), *mahewu* (South Africa), *kobo sour water* (Ghana), *mangisi* (Zimbabwe), *obushera* (Uganda), *malwa* (Uganda), *masvusvu* (Zimbabwe), and *obiolor* (Nigeria); (v) condiments such as *dawadawa* or *iru* (West Africa) from African locust bean and soybean, *maari* (Burkina Faso) from baobab seeds, *ogiri* or *ogili* (Nigeria) from *egusi* melon (*Colocynthis citrullus*) seeds, *ugba* or *ukpaka* (Nigeria) from African oil bean seeds, *okpehe* (Nigeria) from *Prosopsis africana* seeds and *bikalga* (Burkina Faso) from roselle (*Hibiscus sabdariffa*) seeds (Aka et al., 2014; Anyogu et al., 2021; Mokoena et al., 2016). African fermented foods from animal sources are less widespread than plant-source foods. However, traditional fermented milks such as *nono* or *nunu* (Nigeria, Ghana), *lait caille* (Burkina Faso, Senegal), *mursik* (Kenya), *mabisi* (Zambia), *leben/iben* (North Africa), *Gariss* from camel milk (Sudan) and fermented milk-cereal mixtures known as *fura-da-nono* and *kunu-da-nono* (Nigeria) are important sources of animal protein in many parts of Africa (Anyogu et al., 2021; Beukes et al., 2001). Other traditional dairy products in Africa that are important components of diets include yoghurts such as *kindirmo* and *amasi*, and cheeses such as *warankasi*, *jben* and *klilia*. Fermented meats such as *kaddid, soudjouk, sucuk, nakanek, boubnita, pastirma or basturma* and fermented fish such as *momoni* and *lanhouin* are more popular in North Africa and coastal regions of Africa respectively (Anihouvi et al., 2012; Anyogu et al., 2021; Gagaoua & Boudechicha, 2018; Mokoena et al., 2016).

4.2. Health benefits and food safety issues associated with traditional fermentations

Part of the continued interest in fermentation technology stems from the fact that it is considered "natural" and some of the microorganisms involved are probiotics. Apart from improvements in nutritional value, protein digestibility and reduction of nutritional stress factors due to fermentation, the reduction in pH due to lactic, acetic and propionic acids and diacetyl produced by LAB inhibits many microorganisms including pathogenic and spoilage bacteria and fungi (Adinsi et al. 2017; Ganzle, 2015; Mpofu et al., 2016). Other antimicrobial metabolites associated with LAB metabolism include bacteriocins, ethanol and hydrogen peroxide (Mokoena et al., 2016; Oguntoyinbo & Narbad, 2015). Bacteriocins are potent antimicrobial peptides, that are very effective, particularly against Gram-positive bacteria (Anukam & Reid, 2009; Cintas et al., 2001). Some LAB are part of the gut microbiome and they may help in the restoration of gut microbiome after antimicrobial therapy. They also produce vitamins and may help stimulate immune response (Markowiak & Slizewska, 2017). Other recently reported probiotic applications of LAB include reduction of the risk of dental caries by *Lactobacillus rhamnosus*; mitigation of Type II diabetes and obesity by *Lactobacillus casei*; lowering of cholesterol and low-density lipoproteins by *Bifidobacterium longum* SPM 1207 and *Lactobacillus* spp.; inhibition of *Listeria monocytogenes and Clostridium* spp. by *Lactobacillus* spp.; modulation of immune system and promotion of mental health by *Lactobacillus acidophilus, Lactobacillus salivarius*, *Lactobacillus rhamnosus*, *Lactobacillus brevis* and *Lactobacillus casei*; reduction of mycotoxins in fermented maize products by *Lactobacillus* spp.; the use of *Lactobacillus reuteri* and *Lactobacillus plantarum* as antifungal agents, and *Lactobacillus casei* and *L. plantarum* as drug-delivery vehicles (Mokoena et al., 2016).

Despite the health benefits of fermentations and the fact that African fermented foods are largely safe due to LAB, there are some food safety concerns associated with African traditional food fermentations largely on account of the raw materials, packaging materials, and unhygienic conditions under which the foods are produced (Adinsi et al., 2017; Anyogu et al., 2021; Oguntoyinbo, 2014). The use of cassava varieties with high amounts of cyanogenic glucosides and poor processing techniques could lead to high cyanide levels, exceeding the recommended 10 mg/kg, in cassava products like *garri* and *kivunde* (Abiodun et al., 2020; Aworh, 2010; Kimaryo et al., 2000). The raw materials used and processing conditions were linked to potential mycotoxin contamination and the presence of cyanogenic compounds in *gowe*, a malted and fermented cereal beverage from West Africa, while the occurrence of *E. coli* and *Enterobacteriacae* in the product was linked to inappropriate handling and packaging material (Adinsi et al., 2017). Concerns over mycotoxin contamination of the wide variety of African traditional beverages produced from cereals that are heavily contaminated with multiple mycotoxins due to poor agricultural, post-harvest handling and storage practices have been discussed in a comprehensive review (Ezekiel et al., 2018).

Bacillus species such *B. subtilis*, *B. licheniformis* and *B. pumilus* are the dominant microorganisms in the production of important traditional fermented food condiments of West and Central Africa like *dawadawa* or *iru*, *ogiri* or *ogili*, *ugba* or *ukpaka* by alkaline fermentation of high-protein legumes such as soybeans and other plant food items like African locust bean and seeds of *egusi* melon, castor oil, fluted pumpkin and African oil bean (Aworh, 2014; Dakwa et al., 2005; Odunfa & Oyewole, 1997). *Bacillus* species are also present in fermented cassava products and are associated with the production of enzymes that hydrolyze cassava resulting in textural changes that occur during cassava fermentation (Amoa-Awua & Jakobsen, 1995). Even though there are variations from place to place, Table 1 describes in general the objectives and main features of the production of important fermented food condiments of West and Central Africa. The unit operations are all carried out manually, often under unhygienic conditions, and include boiling of raw seeds, dehulling, boiling of the dehulled seeds, wrapping/covering and fermenting. The use of spontaneous fermentation processes or back-slopping involving the reuse of utensils from a previous fermentation may lead to the introduction of spoilage or pathogenic organisms (Table 1). *B. cereus*, *Staphylococcus aureus* and *Listeria monocytogenes* are among pathogenic organisms reported in African traditional fermented foods (Anyogu et al., 2021). Another safety concern with regards to African traditional fermented foods is foodborne antimicrobial resistance (AMR) in bacteria that reduces the options for treating human and animal diseases. Available reports on antibiotic resistant bacteria associated with African traditional fermented foods have recently been reviewed (Anyogu et al., 2021). The presence of foodborne pathogens and indicator microorganisms that are resistant to antibiotics including vancomycin, often used as a treatment of last resort, have been reported in some traditional fermented foods including dairy, cereal, vegetable and oilseed products from different parts of Africa (Anyogu et al. 2021). Given the critical importance of foodborne AMR to food safety and public health, there is the urgent need for monitoring and surveillance of AMR in food chains in Africa as is the case in developed economies (Nutty et al., 2016).

Table 1
Common unit operations of traditional fermentation of food condiments of West and Central Africa.

Operation	Objective	Major features
Boiling of raw seeds	To soften and tenderize the seeds.	Boiling is done for 3–12 h or longer depending on the type of seed.
Dehulling of seeds	To remove the outer coating of the seeds and expose the cotyledons.	Carried out by gentle pounding in a mortar with pestle or by rubbing the seeds between the palms or trampling under feet. Sand or other abrasive agents may be added to facilitate dehulling depending on the type of seed.
Boiling of dehulled seeds	To further soften and tenderize the seeds.	Boiling of the dehulled seeds is done for 30 min to 2 h depending on the type of seed; a softening agent may be added during this second boiling depending on the type of seed.
Wrapping/ covering of dehulled seeds	To provide conducive environmental conditions that promote fermentation.	Dehulled seeds are wrapped in banana leaves or covered with raffia mats or jute bags.
Fermentation	To transform the seeds and impart desirable organoleptic qualities of the food condiment; inhibit spoilage and pathogenic organisms; improve nutritional value or digestibility.	Natural fermentation with naturally occurring microorganisms for 2–3 days. Microbial selection by substrate composition and back-slopping. Bacillus spp predominate, lactic acid bacteria and yeast are present in low numbers.

5. Unfermented African traditional beverages

A variety of unfermented traditional beverages are produced from lesser-known, indigenous African fruits and vegetables. Even though the procedures and recipes used for the production of these unfermented traditional beverages vary, there are some common unit operations and these are summarized in Table 2. The process starts with extraction followed by straining to separate the solid materials. Sugars, spices and other ingredients may be added to the resultant liquid, depending on the type of product, which is then packaged. Refreshing drinks are produced in many African countries from the calyces of red varieties of roselle which are rich in protein (17%), crude fiber (9%) and ascorbic acid, 64 mg/100 g (Babalola et al., 2001). These home-made drinks known as 'soborodo' or 'zobo' in Nigeria are pinkish to wine-red or deep red in color and are widely consumed in urban centers as they are very cheap compared with carbonated and non-carbonated beverages produced by food multinationals (Aworh, 2014). Roselle is rich in anthocyanins which are easily leached from the calyces when extracted with water in the preparation of roselle drinks (Aworh, 2014). Several procedures are used but they all involve extraction with boiling water followed by filtering to obtain the juice. The acidic juice (pH 2.5–4.0) is usually sweetened with sugar and various flavors may be added (Aworh, 2014). Similar traditional beverages are also produced from the fruit pulp of tamarind in several African countries using different recipes and methods. Tamarind fruit pulp is rich in sugar and tartaric acid which gives it a unique sour taste and a variety of local beverages are produced

Table 2
Common unit operations for production of unfermented traditional beverages from fruits and vegetables.

Operation	Objective	Main features
Extraction	To express/remove the juice from the fruit or vegetable.	This is carried out by disrupting the fruit or vegetable or leaching out the components in water with or without heat.
Straining	To separate the juice from the pomace.	Juice is separated from the solid materials using fine sieves or by filtering through muslin cloth.
Formulation	To incorporate other raw materials to obtain desired organoleptic attributes of the product.	Sugars, spices and other ingredients may be added depending on the type of product.
Packaging	To contain and preserve the product.	This involves the use of discarded containers such as plastic water bottles that have been previously used for the packaging of other products.

from it in Mali, Ghana and Burkina Faso (Chimsah et al., 2020). In northern Nigeria, traditional beverages are produced from tamarind fruit pulp using procedures and recipes that vary depending on locality (Adeola & Aworh, 2010). For the production of *tsimi*, tamarind pulp is soaked in water for two days, followed by addition of ground ginger, pepper and sugar. *Tsamia* is prepared using the same procedure as *tsimi* except that ground ginger and pepper are not added. The infusion from *tsamia* may be added to *kunu* to produce *kunu tsamia* (Adeola & Aworh, 2010).

Non-fermented traditional beverages from lesser-known indigenous African fruits and vegetables contribute to food and nutrition security as sources of essential vitamins and minerals (Aworh, 2015). However, the traditional techniques used for their production often result in poor quality products with short shelf life that are often microbiologically unsafe. The products are commonly packaged in discarded containers, such as plastic water bottles, that have been previously used for other products. These traditional beverages have been associated with food-borne illnesses such as abdominal cramps, dysentery and diarrhea (Onyelucheya et al., 2001).

6. Upgrading African traditional food processing technologies

Consumers would prefer their traditional foods provided they are well processed, safe and tasty (Gokhale & Lele, 2014). While traditional

Fig. 1. Small cassava processing equipment (Courtesy Nourrit Technol System Limited, Lagos, Nigeria).

foods have been upgraded and are produced on industrial scale in India, Japan and many other countries (Gokhale & Lele, 2014; Qin et al., 2020), traditional foods are still largely produced in the home and by the unregulated informal food sector with little improvement in quality and processing techniques in SSA (Aworh, 2008). However, some progress has been made with the processing of *garri* and other cassava products, the production of yam flour, some traditional beverages and a few other traditional foods that are now produced on small industrial scale with improved technologies in some parts of Africa (Adebo, 2020; Aworh, 2008; Sanni et al., 2006). Traditional *garri* processing in West Africa, like the processing of other traditional foods in SSA, involve slow, labor-intensive manual operations and starts with peeling, washing and grating of cassava roots, followed by fermenting the resulting cassava pulp in cloth bags, dewatering, sifting, roasting and sieving to obtain *garri*. Excluding the labour for harvesting, about 415 man-hours are required to process 10 tons of cassava to *garri* (Aworh, 2008). These manual operations have now been replaced by machines in small-scale industrial processing of cassava products that uses mechanical cassava peelers, graters, hydraulic press for dewatering and mechanical *garri* roasters (garifyers) instead of the traditional cast-iron pans (Fig. 1). Apart from the drudgery associated with traditional food processing, other limitations of traditional food processing include lack of standardization, limited capacity, poor efficiency, poor quality products and food safety concerns (Aworh, 2008, 2010; Taiwo et al., 2002).

The introduction of small machines to replace the manual operations reduces the drudgery associated with traditional food processing and the long preparation time often required, improves occupational safety and reduces the dangers associated with traditional food processing such as bruising of hands in traditional grating of cassava and inhalation of toxic fumes in the roasting of *garri*, and generally improves the quality of life of women who are largely responsible for traditional food processing with attendant benefits for the well-being of the family and the society at large (Aworh, 2008). Mechanization also increases processing capacity and efficiency, and improves the quality and safety of the products (Aworh, 2008, 2010; Sanni et al., 2006). Improving traditional food processing technologies is critical to improving the fortunes of small-scale food processing industries that are crucial to rural development and agro-industrialization in SSA. Small-scale food industries provide employment in rural areas, reduce rural-urban migration and the associated social problems, reduce post-harvest losses, increase farmers' incomes and contribute to food security (Aworh, 2008, 2010, 2015). Regrettably, their rapid growth and development are constrained by infrastructural challenges including inadequate electricity supply, adoption of inefficient or inappropriate technologies, limited access to banks and other financial institutions, high interest rates, low profit margins and other factors (Aworh, 2008, 2015; Taiwo et al., 2002).

Solar drying in which equipment is used to collect the sun's radiation in order to harness the radiant energy for drying eliminates many of the drawbacks associated with the traditional open air, shallow layer drying (Sharma et al., 2009). Solar drying gives faster drying rates, increased drying efficiency and more hygienic and better quality products in terms sensory characteristics and nutritional value (Gallali et al., 2000; Komiloglu et al., 2016; Sharma et al., 2009). Various types of solar dryers including passive or natural circulation solar dryers and fan-driven, active solar dryers, suitable for drying African traditional foods have been developed (Sharma et al., 2009). They are low-cost, easy to fabricate and operate, and can be used by small-scale industries in rural areas. Whilst solar drying is used in many parts of the world, it has not been widely used in SSA because of several constraints including potential safety risks from improperly dried and packaged foods and poor quality control including monitoring of water activity (a_w) to prevent growth of pathogenic and spoilage organisms. There is the need for well-trained personnel with good understanding of drying technology and food safety issues for successful deployment of solar drying for production of African traditional foods (Mercer, 2008).

The 2010 Cape Town Declaration of the 15th World Congress of Food Science and Technology (IUFoST, 2010) called for "adaptation and improvement of traditional foods and processes, while respecting the traditional, ethical, cultural and religious aspects involved." Even though considerable amount of research has been done on improving the quality of African traditional foods, including studies on the nature of the substrates (agricultural raw materials) and the fermenting microorganisms in the case of fermented foods, for example, they remain largely at the bench stage (Anyogu et al., 2021; Kimaryo et al., 2000; Mokoena et al., 2016; Odunfa & Oyewole, 1997). Large-scale food industries, especially the food multinationals, have a great role to play in promoting traditional foods through value added processing, quality control and their marketing capabilities including considerable export potentials (Aworh, 2010). Regrettably, the lack of pilot plant facilities for scaling up research from bench stage to large-scale commercial production is one of the most important constraints to commercialization of research findings and upgrading African traditional foods. Given, the huge cost of modern food pilot plant facilities, the establishment of zonal or regional food pilot plants in Africa by governments in partnership with the private sector will facilitate the commercialization of research findings from African universities and research institutes, improve traditional foods and processes, and promote sustainable food security.

7. Conclusion

African traditional foods and food processing techniques are part of the rich cultural heritage of the people. Fermentation and sun-drying are two of the most important traditional food processing techniques in Africa used for the production of a wide range of processed food products and for low-cost food preservation under non-refrigeration conditions. African traditional foods are still largely prepared in the home and the unregulated informal food sector. Their production is characterized by slow, manual operations; the processes are not standardized and the quality of the products are variable and often poor. There are serious safety concerns with many African traditional foods and beverages largely on account of the unhygienic conditions under which they are prepared, the quality of the raw materials and the packaging. The introduction of small machines reduces the drudgery, increases capacity, efficiency and safety of traditional food processing and the quality of the products. Upgrading African traditional food processing techniques would promote sustainable food security.

Declaration of competing interest

I assert that there is no conflict of interest on my part regarding the manuscript entitled "African Traditional Foods and Sustainable Food Security" submitted for consideration for publication in Food Control.

Data availability

No data was used for the research described in the article.

References

Abiodun, O. A., Ayano, B., & Amanyunose, A. A. (2020). Effect of fermentation periods and storage on the chemical and physicochemical properties of biofortified cassava gari. *Journal of Food Processing and Preservation, 44*(12), e14958. https://doi.org/10.1111/jfpp.14958

Adebo, O. A. (2020). African sorghum-based fermented foods: Past, current and future prospects. *Nutrients, 12*(1111). https://doi.org/10.3390/nu12041111

Adeola, A. A., & Aworh, O. C. (2010). Development and sensory evaluation of an improved beverage from Nigeria's tamarind (Tamarindus indica L.) fruit. *African Journal of Food, Agriculture, Nutrition and Development, 10*, 4079–4092. https://doi.org/10.4314/AJFAND V1019.62888.

Adinsi, L., Mestres, C., Akissoe, N., Vieira-Dalode, G., Anihouvi, V., Durand, N., & Hounhouigan, D. J. (2017). Comprehensive quality and potential hazards of gowe, a malted and fermented cereal beverage from West Africa. A diagnostic for a future re-engineering. *Food Control, 82*, 18–25. https://doi.org/10.1016/j.foodcont.2017.06.019

Aka, S., Konan, G., Fokou, G., Dje, K. M., & Bonfoh, B. (2014). Review on African traditional cereal beverages. *American Journal of Research Communication, 2*(5), 103–153.

Amoa-Awua, W. K. A., & Jakobsen, M. (1995). The role of Bacillus species in the fermentation of cassava. *Journal of Applied Bacteriology, 79*, 250–256. https://doi.org/10.1111/j.1365-2672.1995.tb03134.x

Anihouvi, V., Kindossi, J., & Hounhouigan, J. (2012). Processing and quality characteristics of some major fermented fish products from Africa: A critical review. *International Research Journal of Biological Sciences, 1*, 72–84.

Anukam, K. C., & Reid, G. (2009). African traditional fermented foods and probiotics. *Journal of Medicinal Food, 12*, 1177–1184. https://doi.org/10.1089/jmf.2008.0163

Anyanwu, J. C., & Erhijakpor, E. O. (2010). Do international remittances affect poverty in Africa? *African Development Review, 22*, 51–91.

Anyogu, A., Olukorede, A., Anumudu, C., Onyeaka, H., Areo, E., Obadina, A., Odimba, J. N., & Nwaiwa, O. (2021). Microorganisms and food safety risks associated with indigenous fermented foods from Africa. *Food Control, 129*, Article 108227. https://doi.org/10.1016/j.foodcont.2021.108227

Aworth, O. C. (2008). The role of traditional food processing technologies in national development: The West African experience. In *Using food science and technology to improve nutrition and promote national development*. International Union of Food Science and Technology (IUFoST) (Chapter 3), (Robertson, G. L. & Lupien, J. R. Eds.) https://iufost.org/iufostftp/IUFoST_Case%20Studies-1.pdf.

Aworth, O. C. (2010). *Food technology and national development: A global perspective*. Ibadan, Nigeria: Ibadan University Press.

Aworth, O. C. (2014). *Lesser-known Nigerian fruits and vegetables: Post-harvest handling, utilization and nutritional value*. Ibadan, Nigeria: Ibadan University Press.

Aworth, O. C. (2015). Promoting food security and enhancing Nigeria's small farmers' income through value-added processing of lesser-known and under-utilized indigenous fruits and vegetables. *Food Research International, 76*, 986–991. https://doi.org/10.1016/j.foodres.2015.06.003

Aworth, O. C. (2018). From lesser-known to super vegetables: The growing profile of african traditional leafy vegetables in promoting food security and wellness. *Journal of the Science of Food and Agriculture, 98*, 3609–3613. https://doi.org/10.1002/jsfa.8902

Aworth, O. C. (2020). Food safety issues in fresh produce supply chain with particular reference to sub-Saharan Africa. *Food Control, 123*, Article 107737. https://doi.org/10.1016/j.foodcont.2020.107737

Aworth, O. C., Okparanta, R. N., & Oyedokun, E. O. (2002). Effect of irradiation on quality, shelf life and consumer acceptance of traditional Nigerian meat and fish products. In *Study of the impact of food irradiation on preventing losses: Experience in Africa. IAEA-TECDOC-1291, international atomic energy agency* (pp. 39–45). Vienna: Austria.

Babalola, S. O., Babalola, A. O., & Aworh, O. C. (2001). Compositional attributes of calyces of roselle (Hibiscus sabdariffa L.). *Journal of Food Technology in Africa, 6*, 133–134. https://doi.org/10.4314/jfta.v6i4.19306

Beukes, E. M., Bester, B. H., & Mostert, J. F. (2001). The microbiology of South African traditional fermented milks. *International Journal of Food Microbiology, 63*, 189–197. https://doi.org/10.1016/s0168-1605(00)00417-7

Canagarajah, S., & Thomas, S. (2001). Poverty in a wealthy economy: The case of Nigeria. *Journal of African Economies, 10*, 143–173. https://doi.org/10.1093/jae/10.2.143

Cernansky, R. (2015). The rise of Africa's super vegetables: Long overlooked in parts of Africa, indigenous greens are now capturing attention for their nutritional and environmental benefits. *Nature, 522*, 146–148. https://doi.org/10.1038/522146a

Chimsah, F. A., Nyarko, G., & Abubakari, A. H. (2020). A review of explored uses and study of nutritional potential of tamarind (Tamarindus indica L.) in northern Ghana. *African Journal of Food Science, 14*(9), 285–294. https://doi.org/10.5897/AJFS2018.1744.

Chothani, D. L., & Vaghasiya, H. U. (2011). A review on Balanites aegyptiaca Del (desert date): Phytochemical constituents, traditional uses, and pharmacological activity. *Pharmacognosy Review, 5*, 55–62. https://doi.org/10.4103/0973-7847.79100.

Cintas, L. M., Casaus, M. P., Herranz, C., Nes, I. F., & Hernandez, P. E. (2001). Review: Bacterocins of lactic acid bacteria. *Food Science and Technology International, 7*, 281–305. https://doi.org/10.1177/108201301772660538

Dakwa, S., Sakyi-Dawson, E., Diako, C., Annan, N. T., & Amoa-Awua, W. K. (2005). Effect of boiling and roasting on the fermentation of soybeans into dawadawa (soy-dawadawa). *International Journal of Food Microbiology, 104*, 69–82. https://doi.org/10.1016/j.ijfoodmicro.2005.02.006

DeWaal, C. S., Okoruwa, A., Yalch, T., & McClafferty, B. (2022). Regional Codex guidelines and their potential to impact food safety in traditional food markets. *Journal of Food Protection, 85*(8), 1148–1156. https://doi.org/10.4315/JFP-22-052

Ezekiel, C. N., Ayeni, K. I., Misihairabgwi, J. M., Somorin, Y. M., Chibuzor-Onyema, I. E., Oyedele, O. A., Abia, W. A., Sulyok, M., Shephard, G. S., & Krska, R. (2018). Traditional processed beverages in Africa: A review of the mycotoxin occurrence patterns and exposure assessment. *Comprehensive Reviews in Food Science and Food Safety, 17*, 334–351. https://doi.org/10.1111/1541-4337.12329

Farombi, E. O. (2003). African indigenous plants with chemotherapeutic potentials and biotechnological approach to the production of bioactive prophylactic agents. *African Journal of Biotechnology, 2*, 662–671. https://doi.org/10.5897/AJB2003.000-1122

Farouk, M. M., & Bekhit, A. E. (2012). Processed camel meats. In I. T. Kadim, O. Mahgoub, B. Faye, & M. Farouk (Eds.), *Camel meat and meat products* (pp. 186–204). Oxfordshire, UK: CABI.

Fox, L., & Jayne, T. S. (2020). Unpacking the misconceptions of Africa's food imports. https://www.brookings.edu. (Accessed 18 February 2022).

Gagaoua, M., & Boudechicha, H. (2018). Ethnic meat products of the North African and mediterranean countries: A review. *Journal of Ethnic Foods, 5*, 83–98. https://doi.org/10.1016/j.jef.2018.02.004

Gallali, Y. M., Abujnah, Y. S., & Bannani, F. K. (2000). Preservation of fruits and vegetables using solar drier: A comparative study of natural and solar drying, III; chemical analysis and sensory evaluation data of dried samples (grapes, figs, tomatoes and onions). *Renewable Energy, 19*, 203–212. https://doi.org/10.1016/S0960-1481(99)00032-4

Ganzle, M. G. (2015). Lactic metabolism revisited: Metabolism of lactic acid bacteria in food fermentations and food spoilage. *Current Opinion in Food Science, 2*, 106–117. https://doi.org/10.1016/j.cofs.2015.03.001

Gokhale, S. V., & Lele, S. S. (2014). Retort process modelling for Indian traditional foods. *Journal of Food Science & Technology, 51*, 3134–3143. https://doi.org/10.1007/s13197-012-0844-3

Ihenacho, S. C., Nworu, S. A., Ogueji, E. O., Nnatuanya, I., Mbah, C. E., Anosike, F., Okoye, C., Ibrahim, U. B., Kogi, E., & Haruna, M. (2017). Comparative assessment of proximate content and organoleptic quality of African catfish (Clarias gariepinus) processed by smoking and solar drying methods. *African Journal of Agricultural Research, 12*, 2824–2829. https://doi.org/10.5897/AJAR2017.12599

IufoST, & Cape Town Declaration.. (2010). 15th world congress of food science and technology. *International Union of Food Science and Technology*. https://iufost.org/cape-town-declaration/.

Jay, J. M. (2000). *Modern food microbiology. Sixth edition. Aspen publishers, inc*. Gaithersburg: Maryland, USA.

Kalipeni, E., Iwelunmor, J., Grigsby-Toussaint, D. S., & Moise, I. K. (2018). Africa's epidemiologic transition of dual burden of communicable and non-communicable diseases. In E. Kalipeni, J. Iwelunmor, D. S. Grigsby-Toussaint, & I. K. Moise (Eds.), *Public health, disease and development in Africa* (pp. 3–9). London: Routledge Taylor & Francis Group.

Kimaryo, V. M., Massawe, G. A., Olasupo, N. A., & Holzapfel, W. H. (2000). The use of starter cultures in the fermentation of cassava for the production of kivunde, a traditional Tanzanian food product. *International Journal of Food Microbiology, 56*, 179–190.

Komiloglu, S., Toydemir, G., Boyacioglu, D., Beekwilder, J., Hall, R. D., & Capanoglu, E. (2016). A review on the effect of drying on antioxidant potential of fruits and vegetables. *Critical Reviews in Food Science and Nutrition, 56*(1), S110–S129. https://doi.org/10.1080/10408398.2015.1045969

Markowiak, P., & Slizewska, K. (2017). Effects of probiotics, prebiotics and symbiotics on human health. *Nutrients, 9*(1021). https://doi.org/10.33901/nu9091021

Mercer, D. G. (2008). Solar drying in developing countries: Possibilities and pitfalls. In *Using food science and technology to improve nutrition and promote national development*. International Union of Food Science and Technology (IUFoST) (Chapter 4), (Robertson, G. L., & Lupien, J. R. eds) https://iufost.org/iufostftp/IUFoST_Case%20Studies-1.pdf.

Mokoena, M. P., Mutanda, T., & Olaniran, A. O. (2016). Perspectives on the probiotic potential of lactic acid bacteria from African traditional fermented foods and beverages. *Food & Nutrition Research, 60*(1), Article 29630. https://doi.org/10.3402/fnr. v60.29630.

Mpofu, A., Linnemann, A. R., Nout, M. J. R., Zwietering, M. H., Smid, E. J., & den Besten, H. M. W. (2016). Inactivation of bacterial pathogens in yoba mutandabota, a dairy product fermented with the probiotic Lactobacillus rhamnosus yoba. *International Journal of Food Microbiology, 217*, 42–48. https://doi.org/10.1016/j.ijfoodmicro.2015.09.016

Muyonga, J. H., Aworh, O. C., Kinyuru, J., Manley, M., Nansereko, S., & Nyangena, D. N. (2018). Nutritional and nutraceutical properties of traditional African foods. In E. Kalipeni, J. Iwelunmor, D. S. Grigsby-Toussaint, & I. K. Moise (Eds.), *Public health, disease and development in Africa* (pp. 229–244). London: Routledge Taylor & Francis Group.

Naicker, A., Venter, C. S., MacIntyre, U. E., & Ellis, S. (2015). Dietary quality and patterns and non-communicable disease risk of an Indian community in KwaZulu-Natal, South Africa. *Journal of Health, Population and Nutrition, 33*(12). https://doi.org/10.1186/s41043-015-0013-1

National Research Council. (1996). *Lost crops of Africa. Volume I. Grains. NRC*. Washington, D. C.: National Academy Press.

National Research Council. (2006). *Lost crops of Africa. Volume II. Vegetables. NRC*. Washington, D. C.: National Academy Press.

Njume, C., Gqaza, B. M., George, G., & Goduka, N. I. (2014). Inhibitory and bactericidal potential of some indigenous functional food-plants used in the O. R. Tambo District Municipality of South Africa. *Journal of Biosciences and Medicines, 2*, 34–40. https://doi.org/10.4236/jbm.2014.26006. https://.doi.org/.

Nutty, K. M., Soon, J. M., Wallace, C. A., & Nastasijevic, I. (2016). Antimicrobial resistance monitoring and surveillance in the meat chain: A report from five countries in the European union and European economic area. *Trends in Food Science & Technology, 58*, 1–13. https://doi.org/10.1016/j.tifs.2016.09.010. http//dx.doi.org/.

Oboh, G., & Akindahunsi, A. A. (2004). Change in the ascorbic acid, total phenol and antioxidant activity of sun-dried commonly consumed green leafy vegetables in Nigeria. *Nutrition and Health, 18*, 29–36. https://doi.org/10.1177/026010600401800103

Oboh, G., Raddatz, H., & Henle, T. (2008). Antioxidant properties of polar and non-polar extracts of some tropical green leafy vegetables. *Journal of the Science of Food and Agriculture, 88*, 2486–2492. https://doi.org/10.1002/jsfa.3367

Odunfa, S. A., & Oyewole, O. B. (1997). African fermented foods. In S. Edition, & B. J. B. Wood (Eds.), *Vol. 2. Microbiology of fermented foods* (pp. 713–752). London: Blackie Academic & Professional.

Ogunsola, O. O., & Omojola, A. B. (2008). Quality evaluation of kilishi prepared from beef and pork. *African Journal of Biotechnology, 7*, 1753–1758. https://doi.org/10.5897/AJB08.354

Oguntoyinbo, F. A. (2014). Safety challenges associated with traditional foods of West Africa. *Food Reviews International, 30*, 338–348. https://doi.org/10.1080/87559129.2014.940086

Oguntoyinbo, F. A., & Narbad, A. (2015). Multifunctional properties of Lactobacillus plantarum strains isolated from fermented cereal foods. *Journal of Functional Foods, 17*, 621–631. https://doi.org/10.1016/j.jff.2015.06.022

Okoruwa, A., Tehinse, J., Onuigbo-Chatta, N., & Elere, S. (2022). Overview of Nigerian food safety legislation. *Advances in Nutrition and Food Science*. https://doi.org/10.37722/ANAFS.2022303. ANAFS-234.

Onyelucheya, N. E., Ojimelukwe, P. C., & Onyegbado, C. O. (2001). Traditional beverages in Nigeria: A historical perspective and challenges for the future. *Journal of Sustainable Agriculture and the Environment, 3*, 141–148.

Opande, G. T., Musyimi, D. M., & Kaberia, M. J. (2017). Phytochemical screening and antimicrobial effects of leaf and root extracts of Crotalaria brevidens on Candida albicans, Staphylococcus aureus and Escherichia coli in Maseno (Kenya). *International Journal of Pharmaceutical Science Invention, 6*, 33–40.

Oshewolo, S. (2010). Galloping poverty in Nigeria: An appraisal of government interventionist policies. *Journal of Sustainable Development in Africa, 12*, 264–274.

Qin, D., Hara, Y., Raboy, V., & Saneoka, H. (2020). Characteristics and quality of Japanese traditional fermented soybean (natto) from low-phytate line. *Plant Foods for Human Nutrition, 75*, 651–655. https://doi.org/10.1007/s11130-020-00865-5

Sagar, V. R., & Suresh, K. P. (2010). Recent advances in drying and dehydration of fruits and vegetables: A review. *Journal of Food Science & Technology, 47*, 15–26. https://doi.org/10.1007/s13197-010-0010-8

Sanni, L. O., Adebowale, A. A., Filani, T. A., Oyewole, O. B., & Westby, A. (2006). Quality of flash and rotary dried fufu flour. *Journal of Food Agriculture and Environment, 4*, 74–78. https://doi.org/10.1234/4.2006.920

Schonfeldt, H. C., & Hall, N. G. (2012). Dietary protein quality and malnutrition in Africa. *British Journal of Nutrition, 108*, S69–S76. https://doi.org/10.1017/S0007114512002553

Sharma, A., Chen, C. R., & Lan, N. V. (2009). Solar-energy drying system: A review. *Renewable and Sustainable Energy Reviews, 13*, 1185–1210. https://doi.org/10.1016/j.rser.2008.015

Sidibe, M., Scheuring, J. F., Kone, M., Hofman, P., & Frigg, M. (1998). *More on baobab's homegrown vitamin C: Some trees have more than others-consistently. Agroforestry Today*, 10, 10.

Smith, L. C., El Obeid, A. E., & Jensen, H. H. (2000). The geography and causes of food insecurity in developing countries. *Agricultural Economics, 22*, 199–215. https://doi.org/10.1016/S0169-5150(99)00051-1

Stadlmayr, B., Charrondierre, U. R., Enujiugha, V. N., Bayili, R. G., Fagbohun, E. G., Samb, B., Addy, P., Barikmo, I., Quattara, F., Oshaug, A., Akinyele, I., Annor, G. A., Bomfeh, K., Ene-Obong, H., Smith, I. F., Thiam, I., & Burlingame, B. (2012). *West African food composition table. Food and agriculture organization of the united nations (FAO)*. Rome, Italy.

Stamoulis, K. G., Pingali, P., & Shetty, P. (2004). Emerging challenges for food and nutrition policy in developing countries. The Electronic Journal of Agricultural and Development Economics. *Food and Agriculture Organization of the United Nations, 1* (2), 154–167.

Taiwo, K. A., Oladepo, O. W., Ilori, M. O., & Akanbi, C. T. (2002). A study on the Nigerian food industry and the impact of technological changes on the small-scale food enterprises. *Food Reviews International, 18*, 243–261. https://doi.org/10.1081/FRI-120016205

Teixeira, A., Silva, S., Guedes, C., & Rodrigues, S. (2020). Sheep and goat meat processed products quality: A review. *Foods, 9*(960). https://doi.org/10.3390/foods9070960

UNICEF/World Health Organization/World Bank. (2017). Joint child malnutrition estimates, 2018 edition. http://www.who.int/nutgrowthdb/estimates2017/en/.

Uusiku, N. P., Oelofse, A., Duodu, K. G., Bester, M. J., & Faber, M. (2010). Nutritional value of leafy vegetables of sub-Saharan Africa and their potential contribution to human health: A review. *Journal of Food Composition and Analysis, 23*, 499–509. https://doi.org/10.1016/j.jfca.2010.05.002

Vaughan, I. O., Afolami, C. A., Oyekale, T. O., & Aiyegbokiki, A. O. (2014). An analysis of Nigeria food imports and bills. *International Journal of Economics, Commerce and Management*. II (9) http://ijecm.co.uk.

World Health Organization of the United Nations. (2015). *WHO estimates of the global burden of foodborne diseases. Food borne disease burden epidemiology reference group 2007-2015*. Geneva: Switzerland. WHO.