Chapter 29
Fermented Millet for Porridge Production: A Model for Improved Gastrointestinal Health

Afoakwah A. Newlove, Gustav Komla Mahunu, and Haroon Elrasheid Tahir

29.1 Introduction

Modern lifestyle has greatly influenced the choice of food consumed by people. The nature and demand of work and the need for wealth creation have made people become time conscious, thus making people adapt to the consumption of processed convenient foods than spending long hours in the kitchen preparing food. The need for breakfast food such as porridge is an essential diet for numerous nutritional and health benefits.

Porridge is mostly consumed as a complementary food for children above the age of two in Sub—Sahara Africa, providing nourishment to the sick and as a breakfast staple for adults (Onyango and Wanjala 2018; Rhim et al. 2011). The main ingredients used in the preparation can be grouped into two types; those from humid areas such as maize, finger and pearl millets as well as sorghum, then those from starchy tuber crops such as cassava, potato, or plantain (Onyango and Wanjala 2018; Thaoge et al. 2003). Moreover, according to Šimurina et al. (2018), two types of porridge can be classified based on its consistency: thin and thick porridge. Thick porridge contains less water and tends to be solid-like, whereas thin porridge is more liquid-like and can be sipped like a drink or soup. Half of the nutrients in porridge are carbohydrates (50–60%), followed by protein, which contains about 5–10% from porridge prepared with cereals such as millet (Jackson and Gradmann 2018; Om 2019).

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In recent times, cereal grains has become a significant global source of food for humans (Rathore et al. 2016), while in the past five decades, cereal productivity has doubled. Millet covers a total percent of 11.4 area used for cereals and a percent of 4.1 of the cereal supply (FAOSTAT 2008). Millet can survive under challenging climatic conditions such as less rainfall, no fertilizers, or other stressful biological situation.

There are numerous kinds of millets, they are named as Pearl millet (*Pennisetum glaucum* accounts for 40% of global production), Foxtail millet (*Setaria italica*), Proso-millet (*Panicum miliaceum*), and Finger millet (*Eleusine coracana*). Major seeds are produced by pearl millet, and it is usually consumed by humans (ICRISAT 2007). Barnyard millets (*Echinochloa spp*.) are minor millets. Kodo-millet (*Paspalum scrobiculatum*), Little-millet (*Panicum sumatrense*), Guinea millet (*Brachiaria deflexa* or *Urochloa deflexa*), Browntop millet (*Urochloa ramose* or *Brachiaria ramosa* or *Panicum ramosum*), Teff (*Eragrostitef*) and Fonio (*Digitaria exilis*) are also frequently named millets (ICRISAT 2007; FAO 2009).

Millets are served in many parts of Africa as a primary food component in local foods and beverages, such as fermented or unfermented-bread, porridges, and snack. Millets provides energy proteins, minerals, and vitamins in deprived communities and hard-working regions such as Northern Ghana. Moreover, millets have nutraceutical properties, such as reducing cancer risk, lower blood pressures, cholesterol issues, fat absorption, cardiac disease, gastric issues, and gastrointestinal bulk. They also provide nutritional and positive health care benefits (Rathore et al. 2016). A previous study has shown that primary fermentation of millet grain has been used for several processes, including the preparation of porridge with an innumerable groups of microorganisms, chiefly among them are starch degrading ones, and lactic- acid bacteria (Thirumangaimannan and Gurumurthy 2013).

The fermentation of millet-based porridges is a good alternative for other carbohydrate-rich cereal products with improved digestibility, enhancing gastrointestinal health in all persons. Fermentation of cereal grains is a low-cost food preservation method and an old-styled tradition, which is practiced within indigenous African communities and in most undeveloped countries (Blandino et al. 2003). It enhances the nutritional adequacy and, assimilation of raw-products, again it improves the sensory features of foods, that has been fermented (Borresen et al. 2012; Blandino et al. 2003). Mostly, the micro-organisms may form part of the diet or may be included as a starter culture before pretreating or during the cooking of the product (Mokoena et al. 2016). The usage of lactic acid bacteria (LAB) increases the acid value and decrease the pH substrate, thus hindering many disease causative agents called pathogens (Charalampopulos et al. 2002). Many LAB are utilized as probiotics, well-defined as “live microorganisms, which may confer a health benefit to the host” (FAO/WHO 2002).

This chapter explores fermentation procedures of millet, the methods employed for the preparation of fermented millet porridge, nutritional composition of millet and millet porridge and the significance of fermented porridge on gastrointestinal health.

29.2 Food Crops Used for Porridge

The type of ingredients and preparation of porridge differ from household to household and from one country to another. Oats are used to prepare porridge in the North of Europe and North of America (Šimurina et al. 2018), while rice is the primary ingredient of traditional Korea porridges (Rhim et al. 2011). Moreover, porridges in Sub-Saharan Africa is made from tropical cereals and root crops (Akande et al. 2017; Onyango and Wanjala 2018; Taylor and Emmambux 2008).

29.3 Production and Consumption of Millet

Globally, the area sown for the production of millet is about 38 million hectares, which have maintained relative stability in the last two decades. Its production and yield have risen to about 10% in the past two decades and have remained unchanged. Currently, the worldwide production of millet is about 28 million, with a projected mean yield of 0.75 t/ha. The estimated output trend in two leading producers, Africa and Asia, has indicated an essential difference at the regional production (Figs. 29.1a and 29.1b). The production trends in China have doubled in recent time, so as the consumption irrespective of the past decline in the past few decades. This was due to thorough scientific research work. However, the production trend of millet in Africa has rather seen a boost than a fall, as there is a rise in the production of millet from 8 million to 11 million tons in the past decades. Moreover, the consumption of millet in different countries has been influenced by the socio-economic status (FAO 2001).

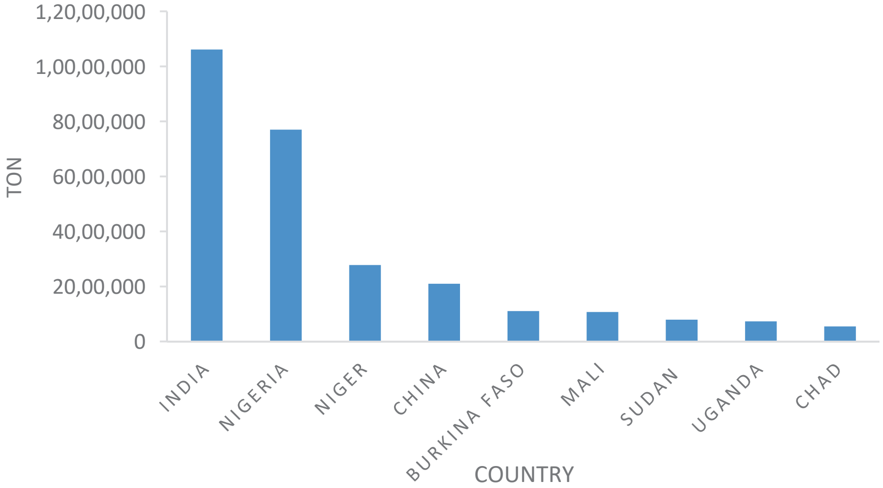

Fig. 29.1a Global millet production in tons, 2007: (Source: FAO 2009)

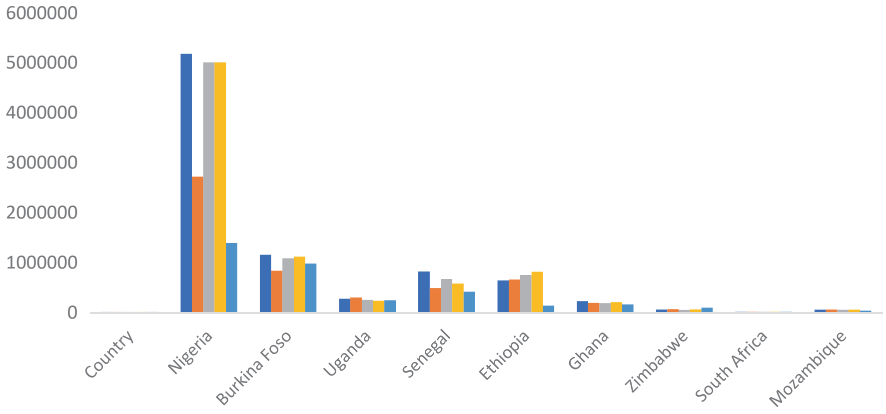

Fig. 29.1b Africa millet production in thousands per tons

29.4 Nutritional Value of Millet

Millets are rich in nutrients such as protein, calcium, and dietary fiber; again, it contains polyphenols (Devi et al. 2011). Table 29.1a signifies amino acid concentration in different kinds of millets. Millets are noted to own significant quantities of essential-amino acids, mostly the sulphur type amino acids, for example, methionine and cysteine. Besides, they contain superior fat content than sorghum, maize and rice. However, millets are inadequate in lysine and tryptophan concentration and may differ based on the type of cultivar, but several kinds of cereal-grains contain vitamins, essential amino acids, and minerals (Devi et al. 2011; FAO 2009).

Whole cereal grains are outstanding source of fiber (Table 29.1b). However, foods processed using grains have noticeable differences in the quantity and kind of dietary fiber component (Shukla and Srivastava 2014). The concentration of dietary fiber in cereal products differs based on the extent of milling. Finger millet has a higher carbohydrate concentration (Table 29.1b) compared to other cereal-carbohydrate (Devi et al. 2011). Millets are sources of minerals, vitamins and fatty acid (Tables 29.1c and 29.1d). Magnesium can decrease or act against headaches and heart attacks, but phosphorus is a vital component of the energy- precursor named adenosine triphosphate in the human body (Badau et al. 2005; Liang et al. 2010; Devi et al. 2011). However, polyphenols in cereals comprises of phenolic acids and tannins, but flavonoids are in minor quantities; they are known to be antioxidant and are responsible for the defense of the body immune network (Chandrasekara and Shahidi 2010; Devi et al. 2011).

Table 29.1a Amino acid profiles of diverse millet grains

Amino acids (g/100 g)	Foxtail millet defatted powder	Proso- millet hulls removed	Pear-millet	Finger-millet
Isoleucine	4.59	4.1	5.1	4.3
Leucine	13.60	12.2	14.1	10.8
Lysine	1.59	1.5	0.5	2.2
Methionine	3.06	2.2	1.0	2.9
Phenylalanine	6.27	5.5	7.6	6.0
Threonine	3.68	3.0	3.3	4.3
Valine	5.81	5.4	4.2	6.3
Histidine	2.11	2.1	1.7	2.3
Tryptophan	NA	0.8	1.2	NA
Alanine	9.30	10.9	8.1	6.1
Arginine	3.00	3.2	0.9	3.4
Aspartic acid	7.71	6.2	6.2	5.7
Cystine	0.45	NA	0.8	NA
Glutamic acid	22.00	21.3	22.8	23.2
Glycine	2.91	2.1	0.7	3.3
Serine	4.56	6.3	5.4	5.3
Tyrosine	2.44	4.0	2.7	3.6
Proline	5.54	7.3	8.2	9.9

Amadou et al. (2013), Kamara et al. (2009), Bagdi et al. (2011), Saldivar (2003) and Devi et al. (2011)

Table 29.1b Proximate composition of some millet varieties

Component g/ 100 g dry basis	Foxtail millet powder	Fonio	Proso millet	Peal millet	Finger millet
Protein	11.50	9–11	11.58	14.8	8.2
Ash	0.47	1–1.1	NA	1.68	2.7
Total CHO[a]	75.2	84–86	80.1	59.8	83.3
Crude Fiber	NA	NA	0.7	12.19	3.5

Source: NA (Not Available)
[a]CHO (Carbohydrate)
Amadou et al. (2013), Kamara et al. (2009), Vodouhe et al. (2003), Bagdi et al. (2011), Taylor et al. (2010), Devi et al. (2011) and Dayakar et al. (2017)

29.5 Useful Microbes for Millet Fermentation

LAB are the organisms needed for cereals-fermentation because of their beneficial role such food preservation, improvement of nutritional value, detoxification, flavour and aroma production. The predominant types are Lactobacillus, Lactococcus, Leuconostoc and Pedicoccus (Salovaara 2004). Other microbes include Corynebacterium, Saccharomyces cerevisiae and Streptococcus. Also, species of mould (Aspergillus, Penicillum, Fusarium and Cladosporium) may be used.

Table 29.1c Mineral content in millet varieties

Nutrients g/100 g	Foxtail millet	Kodo millet	Barnyard millet	Pearl millet	Finger millet
Phosphorus	290	188	280	296	130–250.0
Potassium	250	144	–	307	430–490
Magnesium	81	147–228	82	137	78–201
Calcium	31	27	20–22	42	398.0
Sodium	4.6	4.6		10.9	49.0
Zinc	2.4	0.7	3.0	3.1	2.3
Iron	2.8	0.5–5.0	5.0–18.6	8.0	3.3–14.89
Manganese	0.60	1.10–3.3	0.96	1.15	17.61–48.43
Copper	2.4	1.60	0.60	1.06	0.47

Ramashia et al. (2019), Ravindran (1991), Hassan et al. (2021) and Dayakar et al. (2017)

Table 29.1d Vitamins and essential oil found in finger Millet

Vitamins	mg/100	Fatty acid	g/100 g
Vit A (Retinol)	6.0	Palmitic	21.1–24.7
Vit B1 (Thiamine)	0.2–0.48	Oleic acid	49.8
Vit B2 (Riboflavin)	0.12	Linoleic acid	24.2
Niacin	1.0–1.30	Linolenic acid	1.3–4.40
Vit C (Ascorbic acid)	0.0–1.0	–	–

Hassan et al. (2021), Ramashia et al. (2019) and Dayakar et al. (2017)

29.6 Technique for Millet Fermentation

According to Thirumangaimannan and Gurumurthy (2013); the following are the basic techniques used in the fermentation of millet in millet-based porridge.

29.6.1 Natural Fermentation by Mixing Millets and Water in a 1:2 Ratio of Millet: Water

According to Stefano et al. (2017).

29.6.2 Millet Fermentation Using Water

Add 1 L of water to a hulled millet at different concentrations of 4%, 6%, 7%, 8%, and 10%. Heat the mixture up to 90–95 °C for 60 min. Optionally, add sugar or honey during the last 5 min of pre-treatment. Afterwards cool the mixture to 40 °C then bacterial cultures are added to the mixture.

29.6.3 Milk-Based Fermented Millet

Add 1 L of (3.25%) homogenized milk or 50% water and 50% milk to a hulled millet with different concentrations of 3%, 4%, 6%, 7%, 9%, and 10%. Then, heat the mixture to 85–90 °C for 30–60 min. Optionally, add sugar or honey at the last 5 min of pre-treatment. Subsequently, cool to 40 °C. Then, add bacterial cultures to the mixture.

29.6.4 Flour-Based Fermented Millet

Prepare 1 L of milk, water, or 50%: 50% milk and water respectively. Mix 200 ml milk, water, or 50% (water): 50% (milk) in a bowl containing 152 g of millet flour. Heat the remaining 800 mL milk until it boils. Once it boils, add the wet-flour mixture and stir for 15 min. After the pre-treatment, cool the mixture to 40 °C, finally add bacterial cultures to the mixture.

29.6.5 Dried Fermented Millet

Mix water and millet in a proportion of 2:1 respectively, and then heat to boil. Cool the mixture and let it to simmer under reduce heat until there is water uptake by the millet. After this, cool the mixture at a temperature of 40 °C, then add bacterial cultures to the mixture.

Other alternative techniques have been proposed by Osman (2010).

29.6.6 Traditional Fermentation with Lohoh Preparation

A proportion of 1:2 pearl millet flour and water are combined to make a dough; it is followed by incubation at 30 °C for 24 h using a sanitized covered flask. Before the fermentation starts, starter culture (5% inoculate) is then added to the dough.

29.7 Production of Fermented Millet Porridge

29.7.1 Fermented Millet Porridge in Africa

Millet is commonly used in Africa as a basis of porridge. In West Africa, fermented millet, sorghum, or maize is processed as a traditional gruel or porridge, known as *Ogi* (Blandino et al. 2003) *Ogi* as a weaning meal/ food used to wean infants. This is prepared when the grain is soaked (24–72 h) in water. It is then wet milled, and sieved to eliminate the bran. The eliminated bran may be further undergo fermentation of 2–3 days to produce Ogi (Adebiyi et al. 2018).

In Ghana millet porridge called Hausa *koko*, produced by steeping the pearl millet overnight it is wet milled the with ginger, chilli pepper, black pepper, and clove. Water is added and sieved. Fermentation and sedimentation are allowed to take place for 2–3 h. After fermentation, the upper layer is heated within 1–2 h. Finally, the solidified sediment is added until a perfect uniformity is attained (Lei and Jakobsen 2004; Lei et al. 2006).

Botswana and Southern Africa also have a porridge from fermented maize, sorghum, or pearl millet, known as *bogobe* (*ting*) (Jackson et al. 2013). Similarly, Burkina Faso also has Dèguè (tchobal), prepared by hulling, wet grinding, and steam cooking to obtained gelatinous texture, then fermentation for 24 h is done (Abriouel et al. 2006; Hama et al. 2009).

29.8 General Processes for the Production of Fermented Millet Porridge

In general, the production processes of fermented millet porridge involve soaking process of the grain to soften the grain texture, wet milling, sieving, fermentation using lactic acid bacteria, sedimentation, then cooking (Abriouel et al. 2006; Hama et al. 2009). (Fig. 29.2).

29.9 Nutritional Value of Fermented Millet Porridge

Millets are rich in nutrients (Tables 29.1a, 29.1b, 29.1c, and 29.1d) (Kaur et al. 2012). According Onweluzo and Nwabugwu (2009) the percentage of carbohydrate and protein in millets is about 67% and 12% respectively. Subastri et al. (2015a, b), indicated that the main macronutrients of fermented (finger millet) porridge (koozh) are protein, carbohydrate, glycoprotein, and amino acids, but non-fermented millet porridge contains higher essential amino acids. This may be due to protein converting into peptides and amino-acids (Nkhata et al. 2018; Saleh et al. 2013; Subastri et al. 2015a, b). However, finger millets have higher anti-nutrient (phytates and tannins) concentration, which can decrease nutrient bioavailability. The content of these anti-nutrients can be reduced by utilizing germination and fermentation procedure as a food processing strategy (Makokha et al. 2002; Thuita 2010).

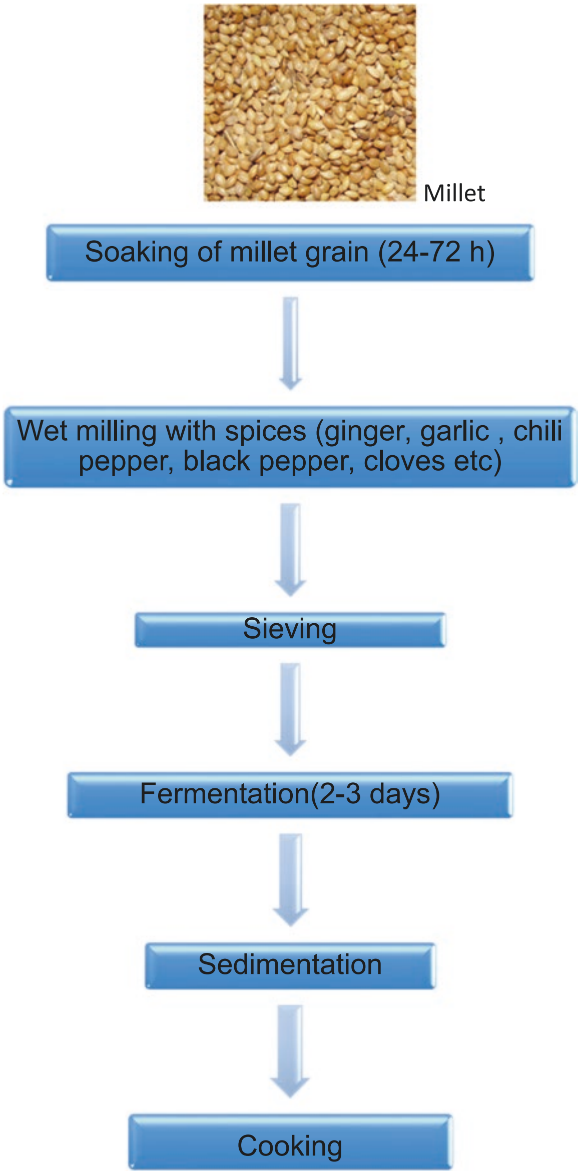

Fig. 29.2 The general procedure for the preparation of millet porridge

29.10 Importance of Fermented Millet Porridge

29.10.1 Potential Food/Nutrient Resource for Growing Population

When cereals are fermented, a higher mineral content, and a lower fat value are obtained, as compared to that of dairy-based counterparts. Fermented cereal based (millet) porridges deliver plant based functional-nutrients, such as fiber, vitamins, minerals, flavonoids and phenolic compounds, which might influence inflammation, oxidative stress, high blood sugar and unusual cell growth in humans (Wang et al. 2013). Producing a uncontaminated porridge from fermented grain (cereal) with cultures of probiotic, may prevent diarrhea and undernourishment caused by un-hygenic traditional-porridges used as a weaning food for children. This may decrease mortalities and improve well-being of consumers (Motarjemi et al. 1993), described an exciting intervention research utilizing fermented probiotic millet product for treating diarrhea in children. An African spontaneous fermented millet porridge called millet-*koko* was explained by Lei and Jacobsen (2004) as a possible probiotic millet-porridge, as well as *Mangisi, Kunu-zaki* and *Uji* a tinny, fermented porridge made from lactic acid (Amadou et al. 2011), also the high nutritional value of millets and its ability to grow in harsh climatic conditions makes it a perfect food source for developing or under developing countries with scarcity of water (Li et al. 2008). As the number of populations rises, it is crucial to find a substitute for staples to make sure the increase of food production is in accordance with the increase of population (Rathore et al. 2016).

29.10.2 Suitable Diet for People with Celiac Disease and Type 1 Diabetes

Patients with celiac disease are counselled to consume a gluten-free strict diet to curtail acute malabsorption, diarrhea, and folate deficiency (Hill et al. 2005; Scaramuzza 2013). Whereas persons having type 1 diabetes are requested to add low-glycemic index food to keep postprandial blood glucose-levels in order (Barclay et al. 2010; Scaramuzza 2013). For instance, Finger millet-grains are gluten-free, and can digest effortlessly. Low glycemic-index of Finger millet grains makes it a fit carbohydrate-containing food choice for celiac disease and type 1 diabetic (Ramashia et al. 2019) patients.

29.10.3 Contributes to the Lessening of Chronic Disease

Millets contain high amount of dietary fiber, carbohydrates, iron, calcium, magnesium, and phosphorus. Consuming this nutrient can decrease the chance of chronic disease, such as ischemic strokes, cancer, and heart disease (Kaur et al. 2012).

29.10.4 Contributes to Gastrointestinal Health

Fermented millet porridge may have an association linking microbial concentration and perfection of the gut microbiota, that is noted to be accountable for the health of people. While it is sometimes uncertain on the functional peculiarity fond in fermented millet porridge that confer farther the underlying nutrition of non-fermented millet porridges, there is corroboration that, some fermented foods give useful results thru direct microbial/probiotic mechanism and indirect way via the process of producing metabolites and a daedal protein breakdown. Fermented-millet porridge may have a link with 'beneficial-bacteria' termed probiotics (Kalui et al. 2010). Probiotics are valuable bacteria that positively modify the intestinal micro-flora, impede the growth of detrimental bacterial, help in digestion, enhance the immune system function and improve resistance to infection (Kalui et al. 2010). Individuals with healthy intestinal colonies made of beneficial bacteria may have the ability to fight disease causing bacteria (Kalui et al. 2010).

29.11 Conclusion

Fermented millet porridge is an essential gluten free breakfast meal suitable for consumption for millions of people of diverse cultural background. Children can rely on it as a complementary food for improving growth as adults and the sick enjoy it as a form of refreshment and a nourishment. The innumerable methods employed for the fermentation process and the preparation of the porridge have helped to improve the utilization of millet and its nutritional benefits. Additionally, the process has assisted in significantly reducing the enzyme inhibitors and phytic acid. The above indications can prove the huge positive impact of fermented millet on the gastrointestinal- health of both adults, the aged and children.

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