Economic, Nutritional, and Health Importance of Finger Millet

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Abstract

Finger millet (*Eleusine coracana*) is a principal cereal crop in many regions, where low-income people are more. Finger millet grains have predominant differences in color as white, brown, and light brown varieties, great value nutritional compounds, high quantity of phytochemicals molecules, enriched with several amino acids (essential), availability of several crucial minerals compounds, and also gluten-free status. Although the grain is rich in several bioactive and nutritionally valuable compounds, finger millet is enormously ignored and remains extensively underutilized. The biochemical composition of finger millet grains has significant contribution in reducing several human health risks such as metabolic diabetic conditions, high blood pressure, and digestive tract illness. Several traditional processing methods are now available and important for proper utilization of grains, for example, malting, soaking, cooking, fermentation, and popping. The available processing methods play a crucial role in improving the nutritive and organoleptic properties and are also very effective in the reduction of anti-nutritional compounds such ds as phenols, physic acids, and tannins in finger millet. Very few studies are available for finger millet utilization and there is an urgent need for further studies on bioactive compounds, improved processing means, nutraceuticals, and product formulations.

2.1 Introduction

Millets are grown as major and significant crops in several regions of the world. Millet crops are recognized as very healthy grain that can be grown on minimal lands with lower water levels. Short growing season under dry- and high-temperature conditions is favorable for their higher productivity. Majority of millet grows and ripens within 70–90 days of the growing period. Millet crops mainly comprise finger millet *Eleusine coracana* (L.), sorghum (*Sorghum bicolor* (L.), kodo millet (*Paspalum scrobiculatum* L.), little millet (*Panicum sumatrense,)* foxtail millet (*Setaria italica* (L.), pearl millet *Pennisetum glaucum* (L.), proso millet (*Panicum miliaceum* L.), barnyard millet *Echinochloa colona* (L.) and *Echinochloa crusgalli* (L.). In

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the developed world, the importance of millets is not very high. At the present condition, the traditional foods are mainly in use for food purposes and major technologies for the purpose of the development of ready-to-cook foods are inadequate. It is found that millet crops have nutritive and health potential comparable to major cereals and many technologies for processing for food development are also available but the use of millet for food is quite limited to major populations in the world and rural populations at the domestic level. The reasons for this are the lack of some more innovative processing technologies, easy to handle, ready to cook, ready to eat, and safety aspects at commercial levels for populations of urban people. In the current scenario, the novel healthy foods products are recognized if their nutritional status is proper and that will also help in convincing the consumer. Major urban consumers prefer breakfast cereals, pasta, noodles, and baked products like bread and biscuits in food.

Increasing demands for healthy foods populations are concentrated on agriculture practices and the production of such types of crops. Consumption of millet grain will increase if process technologies for processing are accessible commercially in millet-consuming countries. Divergence use of food production may play a major role in encouraging production and consumption. The use of whole multigrain food and multigrain substitute are good options for healthy food and healing dietary alteration. Encouraging consumption of millet grain foods is now in practice to decrease the frequency of several diseases in the urban population.

The use of millet grains for food purposes is important in human history, predominantly in Asia and Africa, and has also been cultivated in East Asia for the past 10,000 years. Millet crops are very reliable crops for drought and infertile soils in comparison to other grain crops. The yield of millet on a per hectare basis can improve greatly by suitable irrigation and justifiable soil supplements. The use of advanced breeds of millet can meaningfully increase farm yield production.

2.2 Economic and Nutritional Importance

Keeping up with ideal worldwide public well-being needs promotion of food involved in health and elongation of aging instead of only prevention of chronic illnesses. Presently, there is a greater advancement in medical and health science but we are also facing problems of negative impacts of medicines and their economic burden. In ancient times, it was a well-known dogma that food is the medicine and medicine is the food which specifies that nutrition and its components play a significant role in grand health welfare (Dev et al. 2011). Therefore, the emergent call for healthy food foodstuffs is encouraging revolution and advance in the global scenario. This direction of research and development is mainly concerned with nutrition and health components are designated as nutraceuticals (Chauhan et al. 2013; Keservani et al. 2010; Dev et al. 2011). Several health information advocate the health benefits of nutraceuticals as avoidance and defence against numerous chronic disorders. Therefore, any important change of nutrients due to inopportune nutritive issues affects the health outcome. Presence of health values, whole-grain cereals can be admired as key nutraceutical applicants for human intake and a better lifestyle. This chapter presents a view of finger millet (*Eleusine coracana*), which have several nutritional and nutraceutical qualities to encounter worldwide nutritional disability.

Finger millet comes from the Poaceae family and is usually famous as ragi or madua in India, dagusa in Ethiopia, and rapoko in South Africa (Ignacimuthu and Ceasar 2012). Worldwide, 12–13% of the total millet-producing area is used in finger millet cultivation in more than 25 countries of Africa and Asia and practiced as a major staple food for individuals living with very restricted economic capital. Finger millet can be cultivated on marginal lands, and high altitudes with drought and saline conditions. It needs slight irrigation with little agricultural support but maintains ideal yields.

Finger millet has been reported as the greatest nutritive among all main cereals (National Research Council 1996) and is also thought of as a potential super cereal by the United States National Academies (National Research Council 1996). In view of nutrition, it is extensively rich in minerals which are greater than some key cereal as wheat and rice (Vadivoo et al. 1998; Antony and Chandra 1998). It is reported to be a great source of calcium in comparison to other cereals such as rice, wheat or maize, and milk. Higher contents of iron and fiber, favor this crop as more nutritive. Finger millet has major important amino acids (essential) such as lysine (McDonough et al. 2000) and methionine. Finger millet is also a rich source of some important polyunsaturated fatty acids, for example, linoleic acid and α-linolenic acid (Fernandez et al. 2003), helpful in the brain and nervous system development (Birch et al. 2007; Jacobson et al. 2008). Finger millet is also a good source of vitamins such as thiamine, riboflavin, niacin, and tocopherols (Obilana et al. 2002).

Cultivation and utilization of finger millet are mainly restricted in developing countries with minor farmers having inadequate agricultural resources and referred to as grain of poor people (National Research Council 1996). Even with established health benefits, only a restricted advancement has been made in use as a functional food. Although it has immense potential as nutritional and therapeutic food, it remained underutilized by the common people due to either unfamiliarity or hesitation.

Presently, the commercialization and marketing strategies of finger millet grain increase its opportunities for yield and formulation of several value-added products. Hence, there is an urgent necessity to advance processing technologies such as steaming, soaking, malting, and fermentation for improving the value of the final products. Divergence of value-added foodstuffs would also improve finger millet commercialization aspects. Its exceptional malting value makes it appropriate as a raw substrate for the brewing industry (Taylor et al. 2006). Truly, promoting and demonstrating finger millet and other millets as a healthy food product with greater nutrient excellence shall rise its use in populations who are really aware of their health (Shobana et al. 2013). Numerous reports have emphasized the impact of underutilized grain such as finger millet on revenue generation in both national as well as global markets (Chadha and Oluoch 2007). In case of a developing country like India, by value addition to millet assumed nearly increased two- to threefold farmer incomes and created new employment openings, mainly for females (Vijayalakshmi et al. 2010). This is a great opening to grow markets for non-staple crops which may be a source of income in poor populations (Kahane et al. 2013).

2.3 Finger Millet Grains

Grains of finger millet have low glycemic index and gluten-free crops. (Muthamilarasan et al. 2016; Manjula and Visvanathan 2014). Due to low glycemic index properties, finger millet is found to be a good option for populations with conditions of gluten ingestion and diabetic conditions. Finger millets with the presence of low glycemic index grain may be useful in controlling blood glucose levels (Jideani and Jideani 2011). Finger millet grains are rich in dietary fiber, calcium, and iron minerals in comparison to other cereal grains (Sood et al. 2016). The presence of these minerals is found to be useful in the decline of several diseases such as coronary, cardiovascular, obesity, and diabetic conditions (Kaur et al. 2014; Ramashia et al. 2018). In some reports, it was found that grains of finger millet are very rich in polyphenols and phytates compounds which are familiar to affect the accessibility of some important minerals.

2.4 Morphology of Finger Millet

The grains of the major cultivar of finger millet are brown while a very few with white and red color (Ramashia 2018). Finger millet grains differ from approximately 1.0 to 1.5 mm in diameter (Gull et al. 2014; Siwela 2009). The main structural portions of the finger millet grains are pericarp, germ, and endosperm. The pericarp is an outer layer and contains three layers as epicarp, mesocarp, and endocarp (Ramashia 2018). The pericarp layer is removed during processing as a nonedible part. (Patel and Verma 2015). The endosperm portion is near the seed coat which is utilized in flour making (Palanisamy et al. 2012).

Finger millet is presently used as a significant primary food in various areas of Asia (Gari 2001) as a major functional food. This grain has tremendous potential for boosting food security and rural development and enhances nutritional value (Oduori 2005). Finger millet may play an important role in improving the nutritive and therapeutic features of formulated foods. Millet grain seed is an edible part and a good source of several biochemical components such as phytochemicals, food fibers, polyphenols, and minerals. The presence of essential amino acid, methionine, and several other micro and macronutrients which are not present in poor people's diets make this grain more valuable (Schaafsma 2000).

2.5 Specialty of Finger Millet

Finger millet is presently used as significant primary food in various areas of Asia (Gari 2001) as a major functional food. This grain has tremendous potential for boosting food security, rural development and enhances nutritional value (Oduori 2005). Finger millet may play important role in improving the nutritive and therapeutic features of formulated foods. Millet grain seed is an edible part and a good source of several biochemical components such as phytochemicals, food fibers, polyphenols, and minerals. The presence of essential amino acid, methionine, and several other micro and macronutrients which are not present in poor people's diets make this grain more valuable (Schaafsma 2000).

The soluble dietary fiber present in enough amounts in grains may support in proper regulation of blood glucose and serum cholesterol level (Anderson 1980). It is particularly suggested as healthy food for diabetic persons. Properly processed and regular use in diets of finger millet is well-known to decrease the threat of diabetic conditions (Gopalan 1981) and gastrointestinal tract illnesses (Tovey 1994). Many health-promoting roles was reported in finger millet which evidences its use as nutraceutical food, nutritive, feed, cultural, and medicinal in industrial and economic prospective. It is also reported as a wonder grain because it has a wide variety of range, abiotic stress tolerant, higher storage, and very rich in nutraceutical compounds.

2.6 Nutritive Value

Finger millet grains contain major nutrients which are essential for human use. Grains are extensively rich in protein, dietary fiber, minerals, and some anti-nutritional compounds such as phytates and phenolic compounds. Several studies suggest that finger millet has a decent quantity of beneficial compounds as dietary fibers which is healthy for digestion. Finger millet grains have a very low amount of fat that is appropriate for dietary sources. Finger millet is the best source of some important minerals like calcium, phosphorus, potassium, sodium, etc., and vitamin B complex. Millets also have significant amounts of essential amino acids specifically rich in sulfur. Finger millet grain is also known for amino acids arginine, histidine, lysine, tryptophan, phenylalanine, tyrosine and methionine.

Finger millet grains are also utilized as a whole which is simply consumable with good flavor (Thapliyal and Singh 2015). Finger millet can be served as good source of vitamins and fatty acids (Rurinda et al. 2014). Important health aid of the grains is low discharge of glucose molecules during digestion into the bloodstream (Chappalwar et al. 2013; Mamatha and Begum 2013), which reduces the demand for glucose frequently and reduces constipation (Vanithasri et al. 2012). Millet grains are also linked with lowering the threat of diabetes, effective in blood pressure, cholesterol control, cancer, and cardiovascular diseases (Pradeep and Sreerama 2015; Subastri et al. 2015) (Table 2.1) (Asharani et al. 2010).

Table 2.1 Some important compounds of finger millet grains associated with health (Chandra et al. 2018; Sarita and Singh 2016; Thilagavathi et al. 2015)

Compounds	Biological functions
Phytic acid	Lowering body cholesterol
Phenolic and Tannin compounds	Role in healing and metabolic aging conditions Useful in several cancer and cardiovascular conditions Effective in blood pressure and diabetes
Ferulic acid	In tissue repair Encourage wound curing
Dietary fiber	Help in hypoglycemic and hypolipidemic conditions Effective in serum cholesterol control Effective in atherosclerosis Anti-cancerous properties
Magnesium	As cofactor for enzyme systems Blood glucose control, Blood pressure regulation
Phosphorus	Formation of bones and teeth Body growth and maintenance Repair of cells and tissues

2.6.1 Mineral, Vitamin, and Fatty Acid Content

Finger millet grains are rich in essential minerals, for example, calcium (Ca) and phosphorus (P) and play significant roles in children's development and pregnancy condition (Jideani 2012; Chappalwar et al. 2013). Their role is also very important in obesity, diabetes, and malnutrition (Jayasinghe et al. 2013; Manjula et al. 2015). Regular consumption of finger millet can be very effective for calcium deficiency (Towo et al. 2006). Phosphorus, whose concentration varies from 130.0 to 283.0 mg/g, is also one of the important minerals found in finger millet grains which contribute to the energy metabolic pathway and tissue repairing in the human body (Vanithasri et al. 2012; Ramashia et al. 2018). Some other important minerals present in finger millet grains are iron (3–20%) (Shukla and Srivastava 2014; Rajiv et al. 2011) and magnesium. Both the minerals play a role in the control of blood pressure, asthma, and heart attack (Saleh et al. 2013; Verma and Patel 2013; Prashantha and Muralikrishna 2014). Several reports indicate that finger millet grains have more nutritive value than other millets (Devi et al. 2014; Dlamini and Siwela 2015) (Table 2.2).

Vitamins are also one of the important micronutrient components essential for proper growth and maintenance of the human body and deficiency of vitamins may cause several

Table 2.2 Nutritional composition (proximate and minerals) of finger millet (Dlamini and Siwela 2015; Devi et al. 2014)

	Proximate composition (%)					
Finger millet	Moisture	Carbohydrates	Dietary fiber	Fat	Protein	Minerals
	7.15–13.1	75.0–83.3	15–22.0	1.8	7.7	2.7
	Common minerals composition (mg/100 g)					
	Phosphorus	Potassium	Magnesium	Calcium	Sodium	Iron
	130–250.0	430–490	78–201	398.0	49.0	3.3–14.89

Table 2.3 Major vitamin content and fatty acids of finger millet (Ramashia 2018; Saleh et al. 2013; Ramashia 2018; Serna-Saldivar 2010)

	Vitamins composition (mg/100 g)				
Finger millet	Vit A (Retinol)	Vit B_1 (Thiamine)	Vit B_2 (Riboflavin)	Niacin	Vit C (Ascorbic acid)
	–	0.2–0.48	0.12	1.0–1.30	0.0–1.0
	Fatty acid compositions (g/100 g of total fats)				
	Palmitic acid	Linoleic acid	Oleic acid	Linolenic acid	
	21.1–24.7	24.2	49.8	1.3–4.40	

deficiencies diseases. Finger millet grains contain a good amount of water-soluble vitamins and fat specifically vitamins A and B complex (Table 2.3) (Devi et al. 2014; Chappalwar et al. 2013).

Grains of finger millet also comprise several major essential fatty acids such as linolenic and palmitic acids, which are critical in the improvement of the brain and nerves (Kunyanga et al. 2013; Muthamilarasan et al. 2016). There are very low contents of fatty acids, which have a better shelf life and are helpful in body weight management (Gunashree et al. 2014; Singh et al. 2012; Verma and Patel 2013). Low content of fat and dietary fiber with higher amounts of carbohydrates in finger millet are important for nutritive and physiological aids (Vanithasri et al. 2012; Banusha and Vasantharuba 2013).

2.6.2 Amino Acids Content

Finger millet is very rich in some important essential amino acids. A good amount of approximately 44% of essential amino acids are found in finger millet grains, which mainly include methionine, cysteine and tryptophan, lysine, isoleucine, leucine and phenylalanine, and threonine (Singh and Raghuvanshi 2012; Ramashia et al. 2018; Sood et al. 2017) These components also work in nutrition as well as health aspects (Thapliyal and Singh 2015). The amount of amino acid methionine was reported to be higher than any millet source (Prashantha and Muralikrishna 2014; Singh et al. 2012).

2.6.3 Anti-nutritional Composition of Finger Millet

Some important anti-nutritional compounds reported in Finger millets are phytate, tannins, trypsin inhibitors, and flavonoids. These anti-nutritional compounds are reported to reduce the nutritional properties of finger millet grains (Palanisamy et al. 2012). The major polyphenolic compounds of finger millet are phenolic acids and tannins and the quantity of flavonoids is reported as miner components. The presence of polyphenolic compounds is responsible to keep a good body's immune system against pathogens and clinical conditions (Udeh et al. 2017; Siwela et al. 2007; Devi et al. 2014). Tannins present in the outer layer of finger millet grains function as a physical barrier against fungal pathogens attack (Devi et al. 2014) and are also reported as an important role in several biological functions. A negative impact was reported in case of some anti-nutritional compounds, which are concentrated in finger millet and this compound reduces the digestibility of some nutrient compounds and the absorption of some important minerals.

Tannin compounds are also reported to affect growth due to their adverse impact on the function of some important body organs such as the pancreas, thyroid gland, and liver. These tannin compounds also influence the color, flavor, and nutritional quality of food products developed from finger millet grains. Tannin compounds were also reported for antioxidant activity and help in aging and the avoidance of some important metabolic diseases (Shibairo et al.

2014). Some current findings have presented that some important processing methods can increase the bioavailability of nutrients such as soaking, steaming malting conditions, fermentation conditions, and decortication process (Sood et al. 2017; Sripriya et al. 1997; Platel et al. 2010; Krishnan et al. 2012).

2.7 Use of Finger Millet Grains

Finger millet grains are principally used for the development and preparation of value-added traditional food, a healthy component in nutraceutical food and beverage. The grains can be used in several ways and form in natural and malted forms. The majority of food products developed from finger millet grain and flour in developing nations are not commercialized and not available commercially in the market. In case of sorghum and wheat, many food products are commercially available in big supermarkets around the world (Siwela 2009). Towo et al. (2006) stated that foods formulated from finger millet are not similar in many countries and their grains are found to be healthy for consumption at any stage however, grains are deserted despite their huge nutritive benefits. Many current studies stress prospects for research, health benefits, and utilization of finger millets in developing nations (Table 2.4) (Amadou et al. 2013). These studies may help in reducing heart illnesses, cancers, obesity, and diabetes in these nations (Kaur et al. 2014).

Being gluten-free and rich in fiber, finger millet can prove to be a boon for people with Celiac disease and can be utilized as preventive drug entity for osteoporosis due to its exceptionally high calcium content. Some important processes and technology are useful in the development of value-added products, minimization of anti-nutritional compounds, and enhancement of several nutritional and nutraceutical compounds (Table 2.5). Six finger millet genotypes differing in grain colors, viz., brown, golden, and white were evaluated for their popping quality to select the appropriate genotype for developing ready-to-eat products

Table 2.4 Current research gaps, scientific investigations for utilization of finger millet (Abraham et al. 2014; Jideani 2012; Saleh et al. 2013; Amadou et al. 2013; Verma and Patel 2013; Shukla and Srivastava 2014)

Earlier studies observations	Investigation gap
Necessities of openings in the area of new research and development Establishment of linkage in the field of finger millet research	Technology for commercial development of value-added and suitable processed food products that fulfil requirement of the urban buyer Promote industries to develop finger-millet-based foods
Promotion for consumption, preparation of value-added products and awareness of health benefits	Boost and commercialization for rise in the intake of finger-millet-based food in urban regions is desirable
Intensive nutritive studies	Upcoming developments must be attention on nutritive food from millet
Processing for nutritious and quality food products, upgrading of finger millet grains and their developed food products	Increase extremely improved millet based food products Novel process and technologies for processing and preparation of food products are required which improve micronutrient bioavailability Improve the value of millet foods in human
Promote development of fortified food	Complementary foods formulations and development to achieve the wide gap of food accessibility and food security
Combined with modern food which control metabolic diseases	Commercialization of finger millet food products for patients suffering from diabetes
Conservation of environmental resources to manage the climatic issues in upcoming time	Educate the community and farmers for conservation of environmental resources

Table 2.5 Process and technology for products development

Procedures	Purposes	Type	Reported work
Soaking process	Enhancement in minerals bioavailability	Soaking grains	Saleh et al. (2013)
Malting process	Enhancement in nutritive value, sensual features, and digestibility	Weaning diets	Verma and Patel (2013)
Milling process	Separation of bran, germ, and endosperm and transforms the grain to flour	Flour	Chandra et al. (2018)
Roasting process	Increases the nutritious value and shelf life	Roasted form	Thapliyal and Singh (2015)
Radiation process	•Increases the nutritive value •Decreases the anti-nutrient compounds •Helpful in preserving the foods for longer time	Canned form	Rodrigues et al. (2014)
Cooking process	Help to make palatable and safe Minimize and inactivate anti-nutritional compounds	Porridge form	Kakade and Hathan (2014)
Popping or puffing process	Increase nutritious value Improves taste, color, and aroma	Breakfast, snack, and ready-to-eat foods	Verma and Patel (2013) Neelofar et al. (2014)
Extrusion process	Dehydrated foods preparation	Baby foods, noodles, macaroni, etc.	Rathore et al. (2016)

and for studying the relationship of their physical, nutritional, and biochemical properties with popping quality. Grain hardness, hydration capacity, and moisture content showed a significant relationship with the popping quality (Neelofar et al. 2014).

2.8 Biochemistry for Grain Stability: Factors Affecting the Shelf Life of Pearl Millet Grains

Finger millet is known for protein, dietary fibers, and mineral compounds (Sripriya et al. 1997; Mathanghi and Sudha 2012). It is significant because of its nutritive value. Its dietary fiber and mineral content is markedly higher than wheat, rice, and fairly well-balanced protein (Ravindran 1991). It reported that FM grains contain polyphenols and phytates which are known to influence the availability of minerals (Kaur et al. 2014; Ramashia et al. 2018; Krishnan et al. 2012).

Since it is gluten free, the grain is ideal for people who have gluten allergy. It is widely recognized as the staple food for poor and small landholder populations, and its biochemical composition also supports nutrients and energy. Due to the presence of lipid and unsaturated fatty acids, its flour suffers from problems of oxidative and hydrolytic rancidity which is responsible for the production of unpleasant taste and off-odor during storage (Carnovale and Quaglia 1973). Due to higher lipase activities and rapid release of fatty acids, which limits its shelf life; so the rapid development of off-flavor (Goyal et al. 2017).

Higher rate of hydrolytic cleavage of lipids, occurrence of several volatile compounds, changes in the composition of lipids and oxidative changes in unsaturated fatty acids, enzyme-catalyzed changes in phenolics, presence of C-glycosylflavones and presence of a high concentration of off-odor-generating volatile 2-acetyl pyrroline have been documented as a possible cause for generation of off-odor (Thiam et al.

1976; Bangar et al. 1999). Higher peroxidase and enzyme activities changes in phenolics (Bangar et al.1999; Reddy et al. 1986; Chugh and Sharma 2012) as other causes for generating off-odor in stored flour of finger millet and pearl millet. Hydrolysis of fats in glycerol and fatty acids by lipase enzyme produces free fatty acid compounds and these unsaturated fatty acid compounds oxidized and produce aldehydes, ketones, and other volatile compounds responsible for off-flavor development in pearl millet. Oxidation of free fatty acids by the activity of lipoxygenase produces free radicals, which are the unstable molecules that damage the cells and develop the odors.

2.8.1 Reason and Mechanism of Rancidity in Millet

The biochemical reaction between fat and oxygen degraded the long-chain fatty acids to form the short-chain compounds. In general, the hydrolytic and oxidative rancidity causes the free fatty acids, bitter, mousy acidic, volatile off-odor compounds. Hydrolytic rancidity occurs due to the action of enzymes called lipases and the presence of high levels of peroxidase, or it is the process of breaking down a lipid and producing glycerol and fatty acids which gives a foul odor and flavor. Whereas in the case of oxidative rancidity, it oxidizes the fatty acid chains or carbon–carbon double bonds in unsaturated fat are half broken, thus making it a carbon–carbon single bond and one bond with an oxygen molecule. This process can be catalyzed by light, enzymes, trace metals, and free radical species.

2.8.2 Lipid Oxidation Mechanism

Lipid oxidation consists of three processes such as initiation, propagation, and termination. In the initiation step, non-reactive fatty acid converts into reactive lipid peroxide which is governed mainly by auto-oxidation or enzymatic oxidation. The resulting lipid–free radicals ($R^{\cdot}$) react with oxygen to form peroxy radicals ($ROO^{\cdot}$). The ROO reacts with more RH to form lipid hydroperoxides (ROOH), which are the fundamental primary products of autoxidation.

Decomposition of lipid hydroperoxides (ROOH) is a very complicated process that creates materials with several biological properties which affect flavor deterioration in fat-containing food (Fig. 2.1).

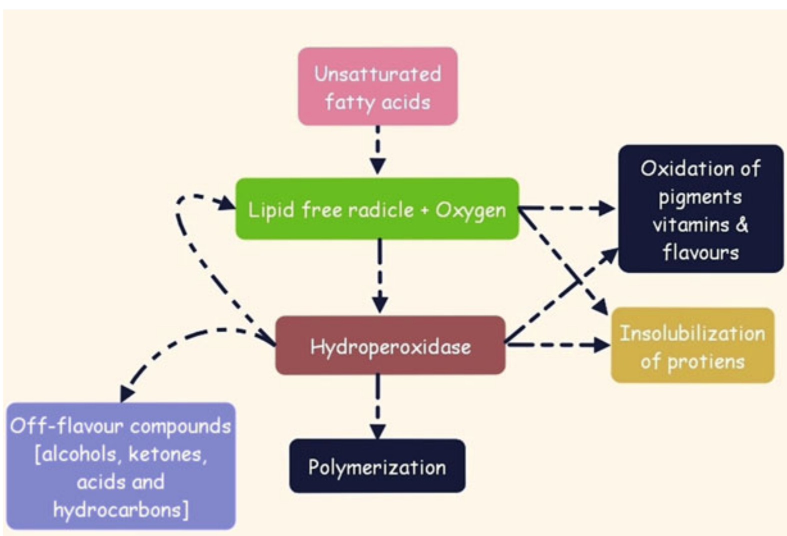

Fig. 2.1 Biochemical mechanism of lipid oxidation in millets

2.9 Factors Affecting the Shelf Life in Millets

The rancid nature of pearl millet grains limits the nutritional benefits of the grains and the off-flavor development restricts the overall acceptability (Goyal et al. 2017). Some of the factors which mainly affect the shelf life of finger and pearl millet or its acceptability are described as follows.

2.9.1 Fat and Fatty Acid Composition

Lipid components is a major factor responsible for the quality deterioration and development of off-odors in millet, especially in the ground one.

2.9.2 Presence of Phenolic Content

Phenolic components are the most significant and secondary products in the majority of grains and have aromatic rings with hydroxyl groups. Several phenolic compounds were also identified and measured in the millets. Usually, catechin was the leading phenolic compound. The mean values reported for the finger millet were 610.4–675.1 mg/kg. Ferulic acid is the major bound phenolic compound in finger millet. In pearl millet, the total polyphenols of flour were reported to be about 228–486 mg/100 g and 175–435 mg/100 g (Chavan and Hash 1998; Kumar et al. 2015). The most common phenolic compound in pearl millet is ferulic acid and its bound form goes through a damaging oxidation response during storage (Ragaee et al. 2014). In the case of pearl millet, polyphenols (Reichert 1979) limit the protein and starch utilization and develops odor during the storage period.

2.9.3 Peroxidase Activity

Peroxidase (POX) is a thermo-stable plant heme-containing enzyme. It catalyzes the oxidation of several unsaturated fatty acids and causes the formation of volatile carbonyl compounds which may contribute to odor (Ashie et al. 1996). Peroxidase enzyme is mainly intense in germ fraction (376 units/g/min) of the grain and found to be responsible for odor generation in case of stored pearl millet meal (Chavan and Hash 1998; Praduman 2006).

2.9.4 Fat Acidity

It was also reported that after milling the fat rancidity increases which is supposedly due to the action of lipase enzyme and causes bitterness and can make millet meal objectionable (Yadav et al. 2012; Arora et al. 2002). Carnovale and Quaglia (1973) in their experiment found that pearl millet flour at 30 °C for 3 months deteriorates in the quality of flour which is mainly by the hydrolysis process rather than the oxidative decay of lipid molecules. Lipase seemed to be more effective in case of defatted millet (Liu et al. 2012; Wang et al. 2014).

2.9.5 Lipoxygenase and Polyphenol Oxidase

The enzyme lipoxygenase catalyzes the oxidation of free fatty acids such as linoleic and linolenic acids. During biochemical reaction, lipoxygenase produces many reactive compounds for example free radicals. These free radicals may react with ascorbic acid, carotenoids, chlorophylls, α-tocopherol, and phenols causing a change of organoleptic and off-odor in products. Banger et al. stated that in several cased polyphenol oxidizing enzymes are a major factor for odor formation in pearl millet (Table 2.6).

2.10 Role of Finger Millet in Nutraceutical Food Development

Several current observations found that nutrition with plant-based foods specifically whole cereals are defensive against numerous illnesses

Table 2.6 Biochemistry for odor generation in pearl millet

Product	Responsible factors	Results	References
Pearl millet	Lipase	Loss of essential amino acids and biological value leads to an off-odor	Kadlag et al. (1995)
Flour	Lipid, Unsaturated fatty acids	Unpleasant taste and off-flavor	Kapoor and Kapoor (1990)
Pearl millet grain	Lipolysis and oxidation of unsaturated fatty acids	Off-flavor	Lai (1980)
Pearl millet flour	Peroxidase activity, Lipids and phenolics	Rancid odor	Goyal et al. (2017)
Grain	lipases, peroxidases and phenolics content	Off-flavor	Chugh and Kumar (2004)
Ground pearl millet	Increase in fat acidity and peroxide value	Rancid odor	Kaced et al. (1984)
Pearl millet	Water-soluble phenolics and peroxidase activity	Odor Generation	Bangar et al. (1999)
Flour	Phenol content and peroxidase	Off-flavor and mousy odor	Yadav (2003)

conditions such as diabetes, cardiovascular, some cancers condition, and metabolic syndrome diseases. Finger millet grain is found to store a house of healthy compounds such as proteins, dietary fibers, micro and macronutrients, and several phytochemicals vital for human well-being (Table 2.7). Developing nutraceutical food using finger millet must be required for biochemical and safety evaluation of ingredients. Polyphenolic compounds of finger millet (about 0.3–3%) are familiar for their health benefits such as hypoglycemic conditions, hypo-cholestrolemic conditions, and many other disease conditions (Pradhan et al. 2010). In common, it is supposed that the polyphenolic compounds of small millets have key valuable roles as antimicrobial, antioxidant, and inhibitory activities against several enzymes (Chethan et al. 2008). Polyphenolic compounds of millets are familiar to inhibit the activity of several digestive enzymes such as amylase, pepsin, trypsin, glucosidase, and lipases (Rohn et al. 2002). They show an important role in the inhibition of amylase enzyme activities and therefore effective to manage type 2 diabetes and contribute to controlling high glucose levels in the blood (Saito et al. 1998). They are also reported to act as inhibitors of amylase and glucosidase and cause a reduction in postprandial hyperglycemia (Bailey 2001). Very little information is available for variations in polyphenolic contents among millet varieties (Chethan and Malleshi 2007a, b). Inhibitory activity against snake venom phospholipases A2 (PLA2) and cataract formation was reported by Chethan et al. (2008). Chethan and Malleshi (2007a, b) also studied several brown and white varieties and stated higher polyphenols in brown varieties in comparison to white varieties. It is also confirmed that the phenolic compounds present in millets are heat stable, pH-sensitive, and in most cases they are highly stable in the acidic pH range (Chethan and Malleshi 2007a, b).

Presence of high fiber content is useful to control constipation, blood cholesterol, and intestinal cancer (Usha 2004). Due to the low glycemic index value, it is useful in the regulation of plasma cholesterol, total serum cholesterol and LDL cholesterol, and triglycerides and plays a significant beneficial effect on the plasma profile (Enas et al. 2003; Mizutani et al. 1999). The leaf juice of finger millet has been used by women during childbirth because of its diaphoretic, diuretic, and vermifuge properties (Watt and Breyer-Brandwijk 1962). Finger millet

Table 2.7 Finger millet and reported nutraceutical properties

S. No	Compounds	Components	Useful role	Nutraceutical role	References
1	Proteins	Albumins, prolamins	Rich in bioactive peptides and essential amino acids	Keeping proper homeostasis, protein energy balance, natural relaxant	Mathanghi and Sudha (2012)
2	Glycoproteins Low fat contents	Biologically important components	Reduction of glycosylation	Aging	Mathanghi and Sudha (2012)
3	Carbohydrates	Free sugars, starch, cellulose, xylose, fructose, glucose, sucrose, oligosaccharides raffinose, resistant starch	Low rate of digestibility	Effective in glucose metabolism	Mathanghi and Sudha (2012)
4	Fibers	Soluble fiber	Plasma cholesterol control, Plasma glucose control, weight management, reduction in blood cholesterol and blood sugar	Effective in glucose metabolism, effective in CVD, effective in gastrointestinal problems, reduces constipation and cancer	Mathanghi and Sudha (2012), Saleh et al. (2013)
5	Vitamins	Vitamins (water- and fat-soluble)	Absorption of minerals	Blood cells production, anemia	Tatala et al. (2007),
6	Minerals	Potassium, sodium, magnesium, calcium, zinc, manganese, iron	Rich in minerals	Effective in osteoporosis, anemia	Platel et al. (2010)
7	Phytochemicals	Tannins, steroids, polyphenols, alkaloids, terpenoids, lignans, phytocyanins	Antioxidants, modulate immune function	Anti-cataractogenic properties, anti-diabetic, cardiovascular diseases, cancer and aging, cholesterol control lowering	Mathanghi and Sudha (2012), Saleh et al. (2013)

(ragi) is a very popular medicine for liver disease, leprosy, measles, pneumonia, and smallpox (Duke and Wain 1981). Several other significant health favorable properties are also linked to finger millet such as antiviral, anticancer, anti-inflammatory, and platelet aggregation inhibitory activity (Chethan and Malleshi 2007a, b).

Antimicrobial activities reported in finger millets are mainly involved in enhancing the body's defence mechanisms and cause inhibition of the angiotensin-I-converting enzyme (ACE) and may be useful for novel treatments for blood pressure patients, heart patients, and diabetes patients (Mizutani et al. 1999). In some reports, it was found that antimicrobial action on the intestinal microflora indicates pharma features. Inhibitory effect on the growth of some common microbes such as *Salmonella typhimurium* and *Escherichia coli* was also reported with fermented finger millet (Usha et al. 1998).

2.11 Nutraceutical Role of Finger Millet

2.11.1 Role in Antioxidant and Antiaging

Numerous phytochemicals are reported as a good source of dietary antioxidants to protect our body against oxidative harm and regularly involved in the maintenance of physiological balance. Several harmful diseases are linked to oxidative processes mediated by reactive oxygen molecules and examples of such diseases are cardiac disease, diabetes, and cancer. The finger millet grains have several phenolic compounds reported to exhibit antioxidant activity (Chandrasekara and Shahidi 2010; Hegde et al. 2005).

At the current time, dietary plant polyphenols receive several considerations from the health and nutrition sector for their role in several health benefits such as the risk of cancer, cardiovascular aging, and diabetes (Tsao 2010; Scalbert et al. 2005; Kaur and Kapoor 2001). Rao and Muralikrishna (2002) reported that proto-catechuic acid is major free phenolic acid found in finger millet grains. In some other research, it was reported that in total phenolic compounds it has 85% benzoic acid derivatives (Chethan and Malleshi 2007a, b). A diet with a higher level of finger millet (55%) enhances the action of some common antioxidant enzymes, for example, glutathione peroxidase, catalase, and glutathione reductase in rats (Hegde et al. 2005).

A different processing condition of finger millet usually decreases the polyphenol contents and reduces the free radical quenching property and examples of this process are thermal or hydrothermal, germination, decortication, and fermentation (Rao and Murali krishna 2007; Shobana and Malleshi 2007). Collagen cross-linking inhibition properties are also reported in finger millet, thus they can be very effective in slowing down aging (Hegde et al. 2002).

2.11.2 Role as Anti-carcinogenic Agent

In the present time, everyone is looking for the prevention of diseases in a natural way. The use of healthy food for prevention and protection against cancer is one of the good and attractive options. The tumor development rate can be minimized by the regular use of anti-carcinogenic food ingredients. Phytochemicals of finger millet are important nutraceutical constituents rich in anti-carcinogenic properties and can be used as terminators for free radical and active oxygen species (Shahidi et al. 1992). As finger millet ensures a range of such types of ingredients that can suppress the cellular oxidation process and protect from different types of cancers (Kawabata et al. 2000; Mori et al. 1999),

A key component of bound phenolic acids is found to be effective as a natural bioactive chemotherapeutic agent against cancer in finger millet (Griffin 1974). Reports indicate that intake of millets in comparison to wheat or maize cause lowers the danger of oesophageal cancer (van Rensburg 1981). Consumption of phenolic components, tannins, and phytate components of finger millet reduces the rate of cancer initiation and progression in several tissues (Chandrasekara and Shahidi 2011). In silico studies with finger and pearl millet phenolic reported by Singh et al. (2015) also indicates strong anti-cancerous evidence.

2.11.3 Role as Anti-diabetic Agent

Diabetes is one of the important health concerns which is rapidly increasing in society in many countries as well as in India. It is an important chronic metabolic disease analyzed by hyperglycemic conditions. It is due to either insufficient insulin production (type-1) or error in action (type-2). Phenolic extracts are found to be helpful in this condition (American Diabetes Association, 2010; Kim et al. 2011; Shobana et al. 2009). Finger-millet-based food has inferior glycemic index and encourages a lesser glycemic response (Shukla and Srivastava, 2014; Shobana et al. 2007). Abundant dietary calcium and magnesium in finger millet are suggested to reduce type-2 diabetes risk (Pittas et al. 2006; van Dam et al. 2006). Intake of multigrain comprising nearly 30% finger millet fraction was found to significantly drop the level of plasma glucose (Pradhan et al. 2010).

The presence of several anti-nutritional molecules (tannins, polyphenolic, and phytates) in finger millet can very useful in lowering the glycemic response because they decrease the digestibility and absorption of starch (Kumari and Sumathi 2002). Some experiments on rats have positively evidenced that finger millet in diet accelerated the wound healing properties and later the case of generation of cataracts (Shobana et al. 2010). Methanolic extracts of finger millet favor healthy use in the pathogenesis of diabetes mellitus problems (Hegde et al. 2002). These are some reasons why finger millet is categorized as a favorable ingredient of diabetes-related problems.

2.11.4 Role as Cardiac Protective

Cardiac problem is the main cause of mortality worldwide. Cardiac problems are mainly associated with irregular blood pressure, higher cholesterol issues, hypertension, diabetes and obesity issues. Lower incidences of cardiac were reported in the case of finger millet consuming populations (Gopalan 1981). This action of finger millet is supposed due to its role against hyperlipidemia conditions and therefore, reduced levels of triglycerides and cholesterol were reported in blood serum in rats (Lee et al. 2010). Thus, finger-millet-containing diet shows lower lipid peroxidation which cuts down arteriosclerosis and thus plays a role in safeguarding against heart attack. Some other reports also suggested the role in the control of lipid and antioxidant metabolism in high cholesterol intake in rat models (Vasant et al. 2014; Chandrasekara and Shahidi 2012b). Some dietary fiber components decrease the reabsorption of bile acids and also drop the LDL cholesterol (Chandrasekara and Shahidi 2012c). Fermentation of finger millet also increases their functionality and favors against cardiac (Venkateswaran and Vijayalakshmi 2010).

2.11.5 Role as Anti-Bone Illnesses Agents

The WHO has projected osteoporosis as a leading worldwide healthcare fear next to cardiovascular diseases. Intake of high amounts of naturally available calcium helps in the prevention of bone diseases like osteoporosis. Finger millet is one of the rich sources of calcium (with up to 350 mg/100 g) and is reported to be 5–10 times higher than other cereals (Kumar et al. 2013).

2.12 Finger Millet Bioactive Compounds and Their Use

Millet is primarily known for phytochemicals such as polyphenols, dietary fibers, condensed tannin, phytate, and pigments. The total dietary fiber of the millet grain mainly contains both soluble and insoluble fiber. Hemicelluloses and pectin are significant soluble fibers whereas cellulose is a major portion of insoluble dietary fiber (Malleshi et al. 1986). The composition of phytate is found to differ (0.5–2.0%) and is mainly intense in the seed coat (Ravindran 1991). The presence of several polyphenols in millets are supposed for their nutraceutical characteristics.

Polyphenolic compounds are metabolites of plants that usually deal as a defense for plants contrary to pathogens. In the early age, polyphenols were labeled as anti-nutritional compounds, but presently they are categorized as nutraceuticals. The important phenolic compound and flavonoids (Kuhnau 1976) are now used as antidiarrheal, antibiotics, and anti-inflammatory agents (Saito et al. 1998), and are frequently used in the cure of hypertension, allergies, cholesterol issues, and some other similar disorders (Chung et al. 1998). Naturally present polyphenols in millets differ from the simple structure as phenolic acids to highly polymerized structure compounds such as tannins.

Simple phenols compounds present in different varieties of millets are phenol, cresol, thymol, resorcinol, orcinol, etc., with hydroquinone and their derivatives and phloroglucinol. Phenylpropanoids and more simple phenols are usually covalently linked to cell wall polysaccharides or core lignin (Wallace et al. 1991). Flavonoids signify the most widely scattered group of plant phenolics. Their common structure consists of two aromatic rings connected over three carbons which frequently form an oxygenated heterocycle (Harborne and Mabry 1982). Several studies related to millet and their bioactive compounds indicated that the presence of several biologically active compounds in finger millets is nutritionally very important. These compounds are dietary fibers, minerals, and polyphenols and they also have several possible nutraceutical effects in several biological systems.

Bio-accessibility of several plant-based nutrients is one of the important issues during food formulation and development, which is very important for food nutrients and health (Cardoso et al. 2015). The discharge and action of bioactive compounds in foods are mainly affected by an enzymatic action from the food side or the digestive tract. Fairly few studies have described the bio-accessibility prospective of finger millet bioactive compounds, particularly for some important food compounds such as minerals and phenolics (Tatala et al. 2007; Platel et al. 2010; Chandrasekara and Shahidi 2012a; Hithamani and Srinivasan 2014). The influence of the malting process on the bioavailability of minerals iron, copper, zinc, and calcium in finger millet was assessed by Platel et al. (2010). The malting study found a modest reduction in the mineral contents of millet during the malting process and also an increase in the bioavailability of iron and calcium. In the malting process, it is established to decrease anti-nutritional compounds by activating some endogenous enzymes which result in their break and subsequent decrease in contents. In some other studies, it was stated that the decrease in mineral content is due to the effect of malting on phytate and other anti-nutritional compounds which form complexes with the minerals (Platel et al. 2010).

In some other study, it was found to increase bioavailable iron after the germination process (Tatala et al. 2007). The effect of processing methods was also found on the bio-accessibility of cereal bioactive compounds. These methods cause the release of these compounds by increasing their surface area ratio, bringing the action of some endogenous enzymes and transforming of the bioactive compounds into more active compounds. Some processing methods are sprouting, milling, roasting, fermentation, and enzymatic digestion (Hithamani and Srinivasan 2014). In sprouted methods, the loss of phenolic compounds is found.

In case of sprouting and roasting, a positive impact on the bioavailability of phenolic compounds was found which increased 67% after sprouting. Processing methods were found to increase the activity of the food matrix and change the compounds into more active forms (Hithamani and Srinivasan 2014). Bio-accessibility of phenolic compounds was investigated by Chandrasekara and Shahidi (2012a) and found a great effect of gastrointestinal pH conditions, digestion inside gastric and gastrointestinal conditions on the bio-accessibility of phenolic compounds of finger millet. Protein digestions with the discharge of their grain-bound phenolic are supposed to have high bioavailability. The activity of some endogenous enzymes (such as proteases and esterase) might also involve in the discharge of the phenolic compounds during digestion.

2.13 Conclusion

Health and body well-being is an important issue for all. Finger millet is rich in fiber, minerals, vitamins, and good quality amino acids, which are mainly deficient in the majority of cereals and also have a very high amount of calcium than other cereals. Finger millet is a principal diet in many countries like Africa and South Asia. The grain is willingly consumable, extremely nutritive, and versatile and it can be used in several food preparations as rice, ground to make porridge or flour, or used to make cakes. These amazing characters make them nutritive and climate change compliant crops. Finger millet can be used as an income crop for agriculturalists and also progress the health of the community as a whole. It is important to raise the production and consumption as it is a very low water consuming crop and in the future it becomes a major alternative for food security. However, this great crop is neglected in our community, science, and policies despite its potential to increase the economy. The use of finger millet in marketable food will boost farmers to grow millets and create several opportunities and revitalize the farmers. The addition of millet diets in state-level, national and international feeding programs will support overcoming the current nutrient shortages of protein, calcium, and iron in emerging countries. There is an immediate need for additional research on finger millet to generate more information on FM utilization. The commercialization of value-added fortified finger millet and other gluten-free products has greater potential as the availability of commercialized finger millet products in developed countries will support mitigating the cases of celiac disease and obesity.

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