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Chapter

Millets Cereal Grains: Nutritional Composition and Utilisation in Sub-Saharan Africa

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Abstract

Millets are small to medium size cereal grain crops that are cultivated throughout the tropics and subtropical region. The grains are used for food and fodder for feeding animals around the globe. Millets have great economic, health importance, gluten-free, have low glycemic index and are known as “nutra–cereals”. The grains are mostly utilised as a food source by population with lower socio-economic factors which are traditional consumers in the farm and village levels. They are rich sources of carbohydrates, protein, crude fibre, phytochemicals, minerals, and vitamins. They are processed by using different traditional processes such as soaking, germination, malting, fermentation, milling or grinding, cooking, roasting and popping. Millet grains/flours are utilised and consumed as flat breads, biscuits, snacks, beverages, porridges, chapati, dosa, pastas. There is a need to produce new value-added products from millets which is underutilised crop to improve food security and prevent micronutrients deficiencies.

Keywords: Millets, cereal grains, nutritional composition, health benefits, utilisation

1. Introduction

Millets are cereal crops that belong to the family Gramineae and they are small-seeded species [1–3]. Most millets belong to the tribe Panicoideae apart from finger millet and teff that belong to the tribe Eragrostideae [4–6]. The grains are available in some parts of African countries and they are cheap [7]. They differ from each other by their appearance, grains quality, taste, morphological and biochemical behavior [8]. They are widely grown around the world for food and fodder and are staple food in the West, East, Central and Great Lakes region of Africa as well as in Asia and India [9–11]. The word millet has been derived from the French word “mille” which means thousand, a handful of millet has been referred to contain thousands of grains [12]. Millets are classified with maize and sorghum in the grass sub-family Panicoideae [3, 8]. They are the 6th most important cereal grain crop in the world agricultural production after wheat, maize, sorghum, rice, and barley that are regarded as the major economic grains in the world [13–15]. Millets are resistant to pests and diseases as compared to other cereal grains [1, 13]. They are major food sources for millions of people, especially those who live in hot, dry areas of the world, adapt to harsh environment especially drought conditions. Millets are one of the cereal grain crops
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that are drought-tolerant and have short growing season [15, 16]. They grow well on poorly fertilised and dry soils with short rainfall periods [1, 17]. The grains are cultivated between February and August while harvested in June or January [18]. About 55–60% of worldwide produced millet grains are cultivated in the sub-Saharan Africa including Ethiopia, Kenya, Malawi, Nigeria, Tanzania, Uganda, Zambia, and Zimbabwe (Table 1). Major types of cultivated millet species varieties are finger millet (Eleusine coracana), pearl millet (Pennisetum glaucum), Japanese banyard millet (Echinochloa frumentacea); foxtail millet (Setaria italica) and proso or white millet (Panicum miliaceum) [20, 21].

The millet grains are gluten-free, non-acid forming, easy to digest, low glycemic index and healthy food diet for people with celiac disease – common disease caused by cereal protein ingestion [1, 2, 19, 22]. Other gluten-free cereal grains are maize, brown rice and sorghum while barley, wheat and rye are gluten rich cereal grains [4]. Table 2 and Figure 1 show the major cultivated millet species in the world. Millets are globally grown in different regions from East to West and they are called in different names around the globe which indicate their specific originality such as foxtail millet as Italian millet, proso as French millet and barnyard as Japanese millet [25]. Finger millet originated in East Africa while white fonio (Digitaria exilis), black fonio (Digitaria iburua) and pearl millet originated in West Africa [26]. Table 3 shows various characteristics of millet species and their functions are shown in Table 4.

| Countries                              | Yearly production (in tonnes) |
|----------------------------------------|------------------------------|
|                                        | 2015 | 2016 | 2017 | 2018 | 2019 |
| Angola                                 | 43746 | 42000 | 70000 | 69854 | 53054 |
| Benin                                  | 21640 | 25182 | 24717 | 26143 | 25000 |
| Botswana                               | 555  | 1264  | 1099  | 2462  | 902  |
| Burkina Faso                           | 946184 | 905071 | 828234 | 1189079 | 970176 |
| Burundi                                | 9970  | 10019 | 9955  | 9891  | 9827 |
| Cameroon                               | 98810 | 99015 | 101101 | 103186 | 105271 |
| Central African Republic               | 10000 | 10000 | 10000 | 10000 | 10000 |
| Chad                                   | 592124 | 725677 | 660175 | 756616 | 717621 |
| Congo                                  | 13197 | 13959 | 13896 | 14197 | 14499 |
| Côte d’Ivoire                          | 55200 | 58300 | 61600 | 65000 | 65000 |
| Democratic Republic of the Congo       | 43776 | 41006 | 40887 | 40908 | 40930 |
| Ethiopia                               | 1036444 | 1017059 | 1030823 | 1035630 | 1125958 |
| Gambia                                 | 73420 | 65073 | 52000 | 38000 | 35000 |
| Ghana                                  | 157369 | 159017 | 163484 | 181564 | 190000 |
| Guinea                                 | 224587 | 238777 | 241714 | 214747 | 223220 |
| Guinea-Bissau                          | 14000 | 14000 | 16177 | 18000 | 20000 |
| Kenya                                  | 99000 | 54000 | 54000 | 72000 | 135000 |
| Malawi                                 | 33512 | 19510 | 35121 | 31315 | 34479 |
| Mali                                   | 1864301 | 1806559 | 1492650 | 1840321 | 1878527 |
| Mauritania                             | 2790  | 3145  | 3277  | 3247  | 3218 |
| Morocco                                | 4953  | 4564  | 4312  | 4104  | 3928 |
| Mozambique                             | 10916 | 21000 | 21000 | 19869 | 12832 |
2. Nutritional composition of millet species

Some nutritional values of millets are similar to that of wheat and rice. Millets are staple food for many African countries; however, they are low in macro nutrients such as protein and fat but rich in vitamins and minerals [7]. Millets are a good source of magnesium which reduces the severity of asthma, frequency of migraines, lowers high blood pressure and reduces the risk of heart attacks. These nutrients play important roles in human nutrition [27]. The grains are also a good source of diet for growing children and expectant mothers [28]. They are a good source of phytochemicals such as polyphenols, tannins, and phytic acid which helps to lower cholesterol and reduces cancer risk, high blood pressure, heart disease and diabetes.
Millet is also known as an alkaline forming food. Alkaline based diet is often recommended to get better optimal health and prevent illness/ diseases [7, 29]. Table 5 shows the nutritional composition of some millet’s species. They have higher amount of minerals such as magnesium, manganese, phosphorus, iron, copper, and potassium when compared with corn, sorghum, and wheat [1, 8, 30]. The main nutrients in millets are starch, protein, lipid, dietary fibre, vitamins, and minerals as shown in Table 6. When comparing millet with other cereals, millet contains 75% of carbohydrates and is low in fat (2–5%) content than maize, rice, and sorghum [1, 2, 8]. Other potential health benefits of millets are the development and repair of body tissue, the prevention of gallstones, protection against breast cancer and protection against postmenopausal complications and the reduction of chances of childhood cancer [1, 2]. Millets contain 65–75% of complex carbohydrates.
**Millet Functions**

**Finger millet**
- It prevents tissue damage and stimulates the wound healing process in diabetic rats.
- Prevents cardiovascular disease by reducing plasma triglycerides in hyperlipidemic rats.

**Proso millet**
- Gluten-free and can prevent humans from celiac disease. Helpful in reducing the risk of type 2 diabetes in humans due to a low glycemic index.

**Foxtail millet**
- It prevents colorectal cancer in mice models. Reduces cholesterol level & have an antidiabetic effect on impaired glucose tolerance persons. Capable of attenuating acute ethanol-induced hepatic injury in mice.

**Pearl millet**
- Prevention of celiac disease in humans due to gluten-free property. Stimulates the immune system to prevent the Shigella-induced pathogenicity in the mice model.

**Banyard millet**
- Acts as an inhibitor of cancer by inducing apoptotic cell death in HT-29 human colon cancer cell line. Its phenolic content inhibits the protein glycation and glycoxidation, which plays a crucial role in the progression of diabetes.

**Little millet**
- Prevents from modern metabolic disorders due to the presence of polyphenols.

**Kodo millet**
- Reduce glycemic index and prevents diabetes in the human female model, also have antioxidant activities.

Source: [25].

### Table 4.
*Functions of millet species.*

| Mineral contents (mg/ kg) | Millet | Wheat | Maize | Rice | Sorghum |
|---------------------------|--------|-------|-------|------|---------|
| Phosphorus                | 2400   | 1170  | 990   | 1030 | 350     |
| Potassium                 | 2200   | 1550  | 1200  | 1500 | 240     |
| Magnesium                 | 1000   | 250   | 470   | 350  | 188     |
| Calcium                   | 100    | 170   | 60    | 60   | 27      |
| Sodium                    | None   | 20    | 10    | 20   | 5       |
| Zinc                      | 34     | 8     | 5     | 17   | 3       |
| Iron                      | 48     | 12    | 11    | 12   | 11      |
| Manganese                 | 7      | 5     | NA    | 9    | 1       |

Source: [30]

### Nutrient compositions (g/100 g)

| Minerals (g/100 g) | Millet | Wheat | Maize | Rice | Sorghum |
|--------------------|--------|-------|-------|------|---------|
| Protein            | 7-12   | 11.6-11.8 | 8.1-10.5 | 6.8-7 | 79      |
| Fat                | 2-5    | 1.5-2.0 | 3.8-4.6 | 0.5-1 | 2.8     |
| Minerals           | 1.0-2.3 | 1.5-1.8 | 1.2   | 0.6   | 1.6     |
| Dietary fibre      | 15-20  | 2.0-12.6 | 2.8-13.4 | 4.1  | 2.3-12.8 |
| Carbohydrates      | 65-75  | 71.0-71.2 | 73.0  | 78.2-79.0 | 73.0   |

**Vitamins (mg/100 g)**

| Vitamins            | Millet | Wheat | Maize | Rice | Sorghum |
|---------------------|--------|-------|-------|------|---------|
| Riboflavin          | 0.25   | 0.17  | 0.20  | 0.06 | 0.15    |
| Thiamine            | 0.59   | 0.45  | 0.38  | 0.06 | 0.38    |
| Niacin              | 3.2    | 5.5   | 3.6   | 1.9  | 4.3     |

NA – not applicable.
Sources: [1, 14, 27, 30–32].

### Table 5.
*Nutritional composition of whole grains (at 12% moisture).*
## Contents

| Contents                        | Foxtail millet | Kodo millet | Barnyard millet | Pearl millet |
|--------------------------------|----------------|-------------|-----------------|--------------|
| **Proximate composition (g)**  |                |             |                 |              |
| Moisture                       | 11.2           | 12.8        | 11.9            | 12.4         |
| Protein                        | 11.50–12.3     | 9.8         | 6.2             | 11.6–11.8    |
| Fat                            | 2.38–4.3       | 1.3         | 2.2             | 4.8–5.0      |
| Minerals                       | 0.47–3.3       | 2.6         | 4.4             | 2.2–2.3      |
| Dietary fiber                  | 2.5–8.5        | 2.47        | 1.98            | 11.3         |
| Carbohydrates                  | 60.9–75.2      | 65.9–66.6   | 65.5            | 67–67.5      |
| Energy (kcal)                  | 331            | 309         | 307             | 361–363      |
| **Minerals (mg)**              |                |             |                 |              |
| Phosphorus                     | 290            | 188         | 280             | 296          |
| Potassium                      | 250            | 144         | —               | 307          |
| Magnesium                      | 81             | 147–228     | 82              | 137          |
| Calcium                        | 31             | 27          | 20–22           | 42           |
| Sodium                         | 4.6            | 4.6         | —               | 10.9         |
| Zinc                           | 2.4            | 0.7         | 3.0             | 3.1          |
| Iron                           | 2.8            | 0.5–5.0     | 5.0–18.6        | 8.0          |
| Manganese                      | 0.60           | 1.10–3.3    | 0.96            | 1.15         |
| Copper                         | 2.4            | 1.60        | 0.60            | 1.06         |

Sources: [1, 13, 31].

**Table 6.** Proximate composition and mineral contents of some millet species.

| Phenolic compound             | Foxtail millet | Kodo millet | Barnyard millet | Pearl millet |
|-------------------------------|----------------|-------------|-----------------|--------------|
| Hydroxybenzoic acid and derivatives |                |             |                 |              |
| Methyl vanillate              | —              | —           | —               | 19.8         |
| Protocatechuic acid           | 10.2           | 39.7        | —               | 11.8         |
| p-Hydroxybenzoic acid         | 5.63           | 10.5        | —               | 22           |
| Vanillic                      | 22.1           | 4.01        | —               | 16.3, 7.08   |
| Syringic                      | 93.1           | —           | —               | 17.3         |
| Gentisic acid                 | 21.5           | —           | —               | 96.3         |
| Hydroxycinnamic acid and derivatives |            |             |                 |              |
| Caffeic acid                  | 34             | 276         | —               | 21.3         |
| p-Coumaric acid               | 848            | 767         | —               | 268.9        |
| Trans-ferulic acid            | 631            | 1844        | —               | 637          |
| cis-ferulic acid              | 101            | 100         | —               | 81.5         |
| 8,8′-Aryl ferulic acid        | 19.6           | 94.8        | —               | —            |
| 5,5′-Di ferulic acid          | 62.2           | 173         | —               | 57           |
| Flavonoids                    | 169            | 173         | —               | 71           |

Source: [27].

**Table 7.** Phenolic compound content (μg/g defatted meal) of some millet species.
carbohydrates, 5.6–12% protein, fat, 2–5%, 15–20% crude fibre and 2.5–3.5% minerals.

Millets are rich source of antioxidant activity such as phenolic compounds that contains phenolic acids, flavonoids, and tannins. Phenolic acids are sub-divided into hydroxybenzoic acids, hydroxyinnamic acids, hydroxyphenylacetic acids and hydroxyphenylpropanoic acids (Table 7). The phenolic compounds of millets phenols are reported to have antioxidant, anti-mutagenic, anti-oestrogenic, anti-inflammatory, antiviral effects, and platelet aggregation inhibitory activity [18]. The antioxidant activities of foxtail and proso millets are high because of their high total carotenoid and tocopherol content which range from 78 to 366 and 1.3–4.0 mg/100 g. The grain has good nutritional value however it is mostly consumed by traditional consumers in a tribal community. Its products are scarce in the urban areas as compared to rice ready-to-eat products [7, 29]. The major challenge with millet grains is that the commercial industrial method of processing the grains are not well-known or developed as compared to other cereal grains [29].

3. Processing and utilisation of millet grains/flours

Processing is a technology which is used to convert the cereal grains into an edible form of food products. Millet grains are prepared using modern and traditional technologies such as soaking, germination, malting, fermentation, milling or grinding, cooking, roasting, compositing flour, fortification, irradiation and popping or puffing mostly widely used in rural areas [13, 33, 34]. Traditionally, millet grains are spread and dried in the sun for a period of one week and are stored inside the bags for future use or processing. The grains can be stored for 5 to 10 years. These processes improve the consumption, nutritional composition, and sensory attributes of food products. Various studies has been conducted and the researchers have tried to produced millets products like puffed, popped, flaked, extruded and

| Current | Emerging |
| --- | --- |
| **Foods** | **Foods** |
| • Flours and meals (Africa and India) | • Gluten-free baked products (USA) |
| • Dumplings, porridges, and gruels (Africa and India) | • Ready-to-eat breakfast cereals (USA) |
| • Rice (Africa and India) | • Noodles (Japan) |
| • Couscous (Africa) | • Instant porridges (Africa) |
| • Malt (Africa and India) | • Instant infant foods (South Africa) |
| **Beverages** | **Beverages** |
| • Non-alcoholic fermented beverages (Africa, Europe, and Asia) | • Lager beers and stouts (Africa, USA and Australia) |
| • Cloudy opaque beers (Africa and Asia) | |
| • Spirits (China) | |
| **Animal feeds** | **Animal feeds** |
| • Processed cattle feed (USA and South America) | • Formulated dog food (South Africa) |
| • Bird food (Asia and Africa) | |
| • Poultry feed (Australia) | |
| **Industrial uses** | **Industrial uses** |
| • Starch (USA and Africa) | • Bioethanol from starch (USA) |

*Source: [35].*

**Table 8.**
Current and emerging uses of millets in the world.
Some of the recent studies are promising to produce popped and milled products [7]. Current and emerging food products produced from millet grains/flours are shown in Tables 8 and 9.

Traditional processing of millet products has received poor scientific applications especially in the developing countries and the use of the modern processing technology has been restricted which can help to produce commercialised products in a large industrial volume [13, 42]. The development of value-added and convenient food products in urban areas may be a possible solution for promoting consumption of millet products. Most of the research have been conducted on the development of composite flour and extruded products which also increase the availability of millet products in the urban areas [1, 43]. Presently, food scientists are more interested in neglected small grains such as finger millet to reduce food shortage and hunger in the developing countries such as Nigeria, Uganda, Kenya, Tanzania, and South Africa. People who are living in the developing countries have limited access to animal food products so it is better to consume healthy millet foods that are rich in minerals and vitamin B complex. Animal food products contain high amount of minerals such as iron and zinc [44–46].

### 4. Traditional millet-based products

Millet grains/flours are consumed as flat bread, porridge, roasted and alcoholic and non-alcoholic beverages. They are utilised to bake different baked products (cookies, biscuits, bread and muffins) and weaning food. Composite flours are utilised to make chappati, puti and murukul, supplementary foods for feeding babies or infants. Some traditional products produced from millets are burfi, baddis, halwa and papad. They are also utilised to replace commonly used cereals in local community dishes like idli, dosa, puttu, adai [27], khichdi, millet ball “fura” and tuwo. Other products that are produced from millet grains/flours are traditional foods and beverages such as snack, fast foods, millet wine roti, bread (fermented or unfermented), porridge and millet powder [7]. Table 10 shows the most common indigenous millet-based fermented food and beverage products produced around the world in which liquid drink is the most popular product and microorganisms associated with each product.

**Table 9. Uses of millets.**

| Uses | References |
|------|------------|
| Traditional opaque beer, Busa | [36] |
| Bread, porridge, soup, cake, beer and distilled liquors | [37] |
| Light and thick porridge; Beer called pito | [9] |
| Weaning and infant food preparations, dumpling, porridge and roti | [38] |
| Food products: mauthri, sevatin, kachauri, kachauri, halwa, cheela, cheela, biscuits and halwa | [39] |
| Polenta, couscous, medicinal herb, folk remedy for leprosy, liver diseases, measles. Pneumonia and smallpox | [40] |
| Flour–based foods such as roti, mudde and ambli | [1, 41] |

Roller dried products; fermented, malted and composite flours; weaning foods.
Non-alcoholic beverage products

Some other non-alcoholic beverage products that are produced form different millet species include appalu, samaipayasam and korramurukulu. Appalu is a food product made from pearl millet and Bengal gram flours. The mixed dough is divided into small balls and flattened into round shape. The dough is fried in a hot cooking pan, then fried and served hot with some vegetables or meat. Samaipayasam is a little millet which is also known as samai and it means little millet while payasam means kheer. The food product is prepared by milling roasted groundnuts into fine powder or flour. Little millet is added to boiling water while stirring constantly. After stirring, the jaggery solution is mixed and cooked for a few minutes on low temperature and served hot. Any millet can be used to make this recipe instead of little millet. Korramurukulu is prepared from foxtail millet and Bengal gram flour. The mixed dough is placed by using hand extruder and murukulu extruded is deep-fried until they turn brown [26]. Millet flour can be utilised to produce breakfast meals that are also known as gruels such as “ogi” and “akamu”. They can be consumed with various animal and vegetable products like meat and leafy vegetables that can nourish the human body by providing good nutritional value [52].
6. Conclusion

In general, this book chapter covered the nutritional composition of millets, processing and utilisation of millets grains or flour into traditional based products and non-alcoholic beverages. Different types of millet such as pearl millet, proso millet, kodo millet, finger millet, foxtail millet and little millet are currently being utilised for different purposes (bread, cookies, muffins, chapatti and biscuit). The availability of gluten free value-added millet products globally may help mitigate the incidence of celiac disease and obesity. Therefore, there is a need for commercialisation and development of value-added gluten-free food products from millets.

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