SORGHUM AND MILLETS

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Summary

The world sorghum economy consist of two distinct sectors a traditional, subsistence, smallholder farming sector where most production is consumed directly as food (mainly in Africa and Asia), and a modern, mechanized, high-input, large-scale sector where output is used largely as animal feed (mainly in the developed countries and in Latin America). The future of the sorghum economy is linked with its contribution to food security in Africa, income growth and poverty alleviation in Asia, and efficient use of water in drought-prone regions in much of the developed world. Millet will remain largely associated with the food security of drought-prone human populations. Productivity has lagged, particularly in Africa, because of the severity of this environment and the pressure of human population growth on traditional land-extensive fallow system. In many countries of the world researchers look for the best growing and using possibilities for sorghum and millet of high energy content. Completely new food products can be produced by introducing new types, optimizing growing technologies (watering, weed control, storage conditions, developing instruments etc.), and applying new hydrothermic technologies. The flaked, puffed and extruded sorghum and millet products, with the addition of some nutrients, can considerably enlarge the food variety of the developed countries too.

1. Introduction

Sorghum is the world’s fifth most important cereal, in terms of both production and area planted. Millet, a general category for several species of small grained cereal crops, is the world’s seventh most important cereal grain. Roughly 90% of the world’s sorghum area and 95% of the world’s millet area lie in the developing countries, mainly in Africa and Asia. These crops are primarily grown in poor areas subject to law rainfall and drought where other grains are unsuitable for the production unless irrigation is available.
Sorghum is widely grown both for food and as a feed grain, while millet is produced almost entirely for food. Sorghum and millets constitute a major source of calories and protein for millions of people in Africa and Asia.

2. Sorghum (Sorghum bicolor /L./ Moench)

2.1. History, Taxonomy and Distribution

2.1.1. History

Vavilov considered the old Abyssinian (Ethiopian) areas the centre of origin of sorghum, but others (Harlan, Snowden) thought that sorghum arose in several separate centres and from different species: races durra and bicolor from S. aethiopicum, guinea from S. arundinaceum, and kafir from S. verticilliflorum. According to de Wet the S. verticilliflorum was the first to be domesticated some 3000 to 5000 years ago (David A. V. Dendy 1995).

2.1.2. Taxonomy

Pliny (ca. 60 to 70 A. D.) was the first to give a written description of sorghum and after that there was hardly a mention of it until the sixteenth century. Moench in 1794 established the genus Sorghum and brought the sorghums under the name S. bicolor.

Harlan and de Wet (1971) developed a simplified classification that is in common use. There are a total of 15 races The basic races are bicolor, guinea, caudatum, kafir, durra, and there are ten hybrid races under S. bicolor subsp. bicolor. Sorghum is a cereal of remarkable genetic variability—more than 30,000 selections are present in the world and it is very difficult to classify them. Sorghum belongs to the order of Poales and to the family of Gramineae.

The species Sorghum bicolor covers a wide range of varieties, from white and yellow to brown, red and almost black (Figure 1).
2.1.3. Distribution

Sorghum is a tropical grass grown primarily in semi-arid parts of the world. In Africa, a major growing area runs across West Africa south of the Sahara, through Sudan, Ethiopia and Somalia. It is grown in upper Egypt and Uganda, Kenya, Tanzania, Burundi, and Zambia. It is important crop in India, Pakistan, Thailand in central and northern China, Australia, in the drier areas of Argentina and Brazil, Venezuela, USA, France and Italy. The crop has spread over the drier areas of the world; it does better when it is dry and cool, whereas pearl millet is better adapted to dry hot conditions. Sorghum is a staple food for about 300 millions people worldwide.

2.2. Chemical Composition (Carbohydrates, Proteins, Lipids, Vitamins and Minerals)

Sorghum is similar in chemical composition to corn (Zea mays). A comparison of nutrients in various cereals is presented in Table 1.
### Table 1: Comparison of nutrients in 100-g edible portions of various cereals at 12% moisture

<table>
<thead>
<tr>
<th>Cereal</th>
<th>Protein (g)</th>
<th>Fat (g)</th>
<th>CHO (g)</th>
<th>Crude Fiber (g)</th>
<th>Ash (g)</th>
<th>Energy (kcal)</th>
<th>Calcium (mg)</th>
<th>Iron (mg)</th>
<th>Thiamin (mg)</th>
<th>Niacin (mg)</th>
<th>Riboflavin (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>11.6</td>
<td>2.0</td>
<td>71</td>
<td>2.0</td>
<td>1.6</td>
<td>348</td>
<td>30</td>
<td>3.5</td>
<td>0.405</td>
<td>5.05</td>
<td>0.101</td>
</tr>
<tr>
<td>Brown rice</td>
<td>7.9</td>
<td>2.7</td>
<td>76</td>
<td>1.0</td>
<td>1.3</td>
<td>362</td>
<td>33</td>
<td>1.8</td>
<td>0.413</td>
<td>4.31</td>
<td>0.043</td>
</tr>
<tr>
<td>Maize</td>
<td>9.2</td>
<td>4.6</td>
<td>73</td>
<td>2.8</td>
<td>1.2</td>
<td>358</td>
<td>26</td>
<td>2.7</td>
<td>0.378</td>
<td>3.57</td>
<td>0.197</td>
</tr>
<tr>
<td>Sorghum</td>
<td>10.9</td>
<td>3.2</td>
<td>73</td>
<td>2.3</td>
<td>1.6</td>
<td>329</td>
<td>27</td>
<td>4.3</td>
<td>0.300</td>
<td>2.83</td>
<td>0.138</td>
</tr>
<tr>
<td>Pearl millet</td>
<td>11.0</td>
<td>5.0</td>
<td>69</td>
<td>2.2</td>
<td>1.9</td>
<td>363</td>
<td>25</td>
<td>3.0</td>
<td>0.3</td>
<td>2.0</td>
<td>0.15</td>
</tr>
<tr>
<td>Foxtail millet</td>
<td>9.9</td>
<td>2.5</td>
<td>72</td>
<td>10.0</td>
<td>3.5</td>
<td>351</td>
<td>20</td>
<td>4.9</td>
<td>0.593</td>
<td>0.99</td>
<td>0.099</td>
</tr>
<tr>
<td>Finger millet</td>
<td>6.0</td>
<td>1.5</td>
<td>75</td>
<td>3.6</td>
<td>2.6</td>
<td>336</td>
<td>350</td>
<td>5.0</td>
<td>0.3</td>
<td>1.4</td>
<td>0.10</td>
</tr>
<tr>
<td>Kodo millet</td>
<td>11.5</td>
<td>1.3</td>
<td>74</td>
<td>10.4</td>
<td>2.6</td>
<td>353</td>
<td>35</td>
<td>1.7</td>
<td>0.15</td>
<td>2.2</td>
<td>18.6</td>
</tr>
<tr>
<td>Japanese barnyard millet</td>
<td>10.8</td>
<td>4.5</td>
<td>49</td>
<td>14.7</td>
<td>4.0</td>
<td>...</td>
<td>22</td>
<td>18.6</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Proso millet</td>
<td>10.6</td>
<td>4.0</td>
<td>70</td>
<td>12.0</td>
<td>3.2</td>
<td>364</td>
<td>8</td>
<td>2.9</td>
<td>0.405</td>
<td>4.54</td>
<td>0.279</td>
</tr>
</tbody>
</table>

2.2.1. Carbohydrates

The majority of the carbohydrate in sorghum and millets are starch, while soluble sugar, pentosans, cellulose, and hemicellulose are low. Regular endosperm sorghum types contain 23 to 30% amylose, but waxy varieties contain less than 5% amylose.

Sorghum is a good source of fibre, mainly the insoluble (86.2%) fibre. The insoluble dietary fibre of sorghum and millet may decrease transit time and prevent gastrointestinal problems.

2.2.2. Proteins

Protein content and composition varies due to genotype, and water availability, temperature, soil fertility and environmental conditions during grain development. The protein content of sorghum is usually 11-13% but sometimes higher values are reported (David A. V. Dendy, 1995).

Prolamins (kafrins) constitute the major protein fractions in sorghum, followed by glutelins. Lack of gluten is characteristic of protein composition, and traditionally, the bread which cannot be baked from sorghum and millet is only cake bread.

In contrast to the unbroken protein matrix of wheat grain there are separate protein bodies which can be distinguished in the endosperm of the ripe seeds of the sorghum and millet. Grain protein is notoriously deficient in the essential amino acid lysine.
(except for several new varieties of high lysine sorghum) and pure in the sulphur-containing amino acids.

In vitro studies and in vivo studies with livestock and laboratory animals, indicate that sorghum proteins are generally less digestible than those of other cereals. Sorghum was shown to be 74.5%, compared with 78.5% for corn.

2.2.3. Lipids

Crude fat content of sorghum averages about 3%, which is higher than that of wheat and rice. Fatty acid composition is similar to that of corn oil, with high concentrations of linoleic (49%), oleic (31%) and palmitic acids (14%). Like maize, the energy content of sorghum is high.

Sorghum grain contains about 1.5 ppm of total carotenoids. Apart from maize and durum wheat, sorghum is the only cereal which contains a significant amount of β-carotene, the provitamin of vitamin A, which is important in human physiology.

2.2.4. Vitamins and Minerals

Sorghum is an important source of B vitamins except B 12, and good source of tocopherols. The B vitamins and minerals are concentrated in the aleurone layer and germ. Removal of these tissues by decortication produces a refined sorghum product which has lost part of these important nutrients.

Sorghum is considered a good source of potassium and is practically devoid of sodium. Whole grains are good sources of magnesium, iron, zinc, and copper.

The bioavailability of iron in sorghum is negatively affected by the presence of polyphenols and phytates, but Derman et al. (1980) reported that iron absorption was more than 12 times greater from sorghum beer than from gruel.

Germination, decortication and/or malting and fermentation enhance the nutritional value of sorghum and millets by causing significant changes in chemical composition and elimination of anti-nutritional factors. The mineral and vitamin composition of sorghum are shown in Table 2.

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Pearl</th>
<th>Finger</th>
<th>Proso</th>
<th>Foxtail</th>
<th>Kodo</th>
<th>Teff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca, mg/100 g</td>
<td>0.01</td>
<td>0.33</td>
<td>0.02</td>
<td>0.01</td>
<td>0.01</td>
<td>0.17</td>
</tr>
<tr>
<td>P, mg/100 g</td>
<td>0.35</td>
<td>0.24</td>
<td>0.23</td>
<td>0.31</td>
<td>0.32</td>
<td>0.45</td>
</tr>
<tr>
<td>K, mg/100 g</td>
<td>0.44</td>
<td>0.43</td>
<td>0.32</td>
<td>0.27</td>
<td>0.17</td>
<td>0.31</td>
</tr>
<tr>
<td>Na, mg/100 g</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>Mg, mg/100 g</td>
<td>0.13</td>
<td>0.11</td>
<td>0.14</td>
<td>0.13</td>
<td>0.13</td>
<td>0.18</td>
</tr>
<tr>
<td>Fe, ppm</td>
<td>74.9</td>
<td>46.0</td>
<td>52.0</td>
<td>32.6</td>
<td>7.0</td>
<td>14.9</td>
</tr>
<tr>
<td>Co, ppm</td>
<td>0.50</td>
<td>0.10</td>
<td>…</td>
<td>…</td>
<td>…</td>
<td>0.06</td>
</tr>
<tr>
<td>Cu, ppm</td>
<td>6.2</td>
<td>0.3</td>
<td>8.3</td>
<td>9.2</td>
<td>…</td>
<td>4.4</td>
</tr>
<tr>
<td>Mn, ppm</td>
<td>18.0</td>
<td>7.5</td>
<td>18.1</td>
<td>21.9</td>
<td>…</td>
<td>2.5</td>
</tr>
<tr>
<td>Zn, ppm</td>
<td>29.5</td>
<td>15.0</td>
<td>17.2</td>
<td>21.4</td>
<td>…</td>
<td>6.7</td>
</tr>
</tbody>
</table>

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Table 2: Mineral and Vitamin Composition of Millets and Sorghum

2.3. Anti-nutrients in Sorghum Grain (Tannins, Phytic Acid, Cyanogenic Glycosides)

Anti-nutritional compounds (e.g. protease inhibitors, galacto-oligosaccharides, lectins, ureases, phytates, tannins, phenolics and saponins etc.) are plant constituents which play an important role in biological functions of plants. The effect of these compounds on human and animal organisms is partly negative because they can reduce the digestibility of nutrients and the absorption of minerals. They may also inhibit growth as a result of their negative influence on the function of pancreases and the thyroid gland, and can cause pathological alterations in the liver. According to published data some anti-nutritional compounds can inhibit the formation and growth of several types of tumors.

2.3.1. Tannins (condensed polyphenols)

All sorghums contain phenolic compounds, including phenolic acids and flavonoids. Some contain in the layer under the seed coat condensed polyphenols called tannins but most cultivated sorghums do not contain any. These compounds can affect color, flavor and nutritional quality of the grain and products prepared from it. Tannins protect the grain against insects and birds (conferring a bitter, hit taste).

The tannin content of seeds inhibits the activity of some enzymes and therefore adversely influences protein digestibility and cellulose breakdown. Animal tests have proved that tannin inhibits protein absorption, decreases utilization of minerals and results in some decrease of growth. Feeding pigs with fodder containing 4.21% tannin decreased protein digestibility by 5.6%. Before ripening the tannin content of grain is always higher than after ripening. The tannin content of dark grains is always higher than that of pale grains.
Some white sorghums have pigmentation in the pericarp and testa, due to phenolic compounds.

2.3.2. Phytic Acid

Phytic acid and/or phytates complex with essential dietary minerals such as calcium, zinc, iron and magnesium to make them biologically unavailable for absorption. Sorghum bran contained the highest levels of phytates. Forty to fifty percent of phytate and total phosphorus can be removed by abrasive dehulling.

2.3.3. Cyanogenic Glycosides

Cyanogenic glycosides occur in most sorghum varieties. The main cyanogenic glycoside, dhurrin, which is found mainly in the leaves and germinating seeds of sorghum, can amount to 3-4% of the total dry seedling weight.

In the course of processing germinating seeds, cyanide may be released—a very toxic material. In the traditional food processing techniques (e.g. drying, malting) the cyanide level seemed to be lowered to zero or to well below that considered toxic.

2.4. Use

In the early 1980s an estimated 39% of global production of sorghum was used as food and 54% for animal feed. By 1992-94, 42% of total utilization was for food and 48% for animal feed.

Between 1992-94 and 2005, food sorghum consumption in developing countries (in Africa, Asia, Central America, Caribbean, and South America) is projected to increase from 26 million to over 30 million tons.

Sorghum is eaten in a variety of forms that vary from region to region. In general, it is consumed as whole grain or processed into flour, from which traditional meals are prepared.

There are four main sorghum-based foods:

- Flat bread, mostly unleavened and prepared from fermented or unfermented dough in Asia and parts of Africa.
- Thin or thick fermented or unfermented porridge, mainly consumed in Africa.
- Boiled products similar to those prepared from maize grits or rice.
- Preparations deep-fried in oil.

Per capita consumption of sorghum is highest in Africa. For example, per capita consumption is 90-100 kg/yr in Burkina Faso and Sudan; sorghum provides over one-third of the total calorie intake in these two countries.

The most common and simplest food prepared from sorghum and millets is porridge.
In all cultures traditionally depending on cereals, a range of treatments of the whole seed before milling and sifting has been applied. The treatments procedures are steeping, fermentation, malting, alkali or acid treatment, popping, roasting (dry or wet), parboiling, and drying. One of the aims of seed treatment is to remove the polyphenolic compounds from the seed. Others are to improve storage quality, or to make many kinds of snacks and other popular foods.

The traditional art of food preparation is not standardized and routine procedures have been passed on to the women through generations.

The stiff porridge prepared from maize or cereal mixture (maize, sorghum, pearl millet, finger millet, etc.) in Kenya, Uganda and Tanzania is commonly called *ugali*. The most important fermented thin porridge that is consumed in Nigeria and parts of Ghana is *ogi*. In much of Northern Africa a steamed, granulated product called *couscous*, made from cereal flours (mostly wheat) is highly popular. In West Africa, sorghum, pearl millet, maize, and fonio are used to prepare couscous, although pearl millet is preferred. Sorghum noodles are an important food product in China. Sorghum is used for tortilla preparation either alone or in combination with maize in Honduras, Nicaragua, Guatemala, El Salvador and Mexico.

Roti is an unfermented dry pancake made in India from wheat, sorghum, pearl millet and maize flour.

Sorghum grain is used in the production of two types of beer: clear beer and opaque beer. The latter is a traditional, low-alcohol African beer that contains fine suspended particles. Sorghum is traditionally a major ingredient in home-brewed beer. Small quantities are used in the beer industries in Mexico and USA.

Sorghum is a good source of starch, cellulose, and glucose syrup. Although domestication was primarily for food (and also for beer and sweet stems in Africa, and for brooms in China), crop residues have been valued as animal fodder, building materials, and fuel. By applying hydrothermic technologies (flaking, puffing, extrusion, micronizing) new sorghum and millet products of good quality and good taste can be produced (see Figure 2.)
2.5. Agronomy, yield and production

2.5.1. Yield and production

The world sorghum economy can be broadly categorized under two production and utilization systems:

Group I countries (primarily in Asia and Africa) use sorghum directly for food. The crop tends to be grown in traditional farming systems where fertilizer rates are low and the adoption of improved moisture conservation technologies is limited. Yields generally average less than 1 t/ha and can vary considerably from year to year.

Group II (developed countries and some developing countries) produce sorghum on a commercial basis, primarily for animal feed. The use of modern agricultural practices is widespread, (hybrid seed, fertilizer and improved water management technologies) and yields correspondingly average 3-5 t/ha.

The world’s major sorghum producers and the annual production of sorghum are shown in Figure 3.
2.5.2. Agronomy

Sorghum is a cereal of remarkable genetic variability—more than 30 000 varieties are present in the world sorghum collections.

Traditional farmers (particularly in West Africa) frequently use photoperiod sensitive varieties.

Sorghum is a thermophilic (26-40 °C), drought-resistant plant, which grows slowly at 16-20 °C, and stops growing under 14 °C.

Highest yields are achieved with irrigation. Using good quality hybrid seeds, sorghum green crops can be increased by 60-80% and the yield of seeds can be increased by 40-50%.

Cultivated sorghums are annuals or weak perennials and are essentially non-rhizomatous. The roots will continue to live and support crops. Sorghum plants are 0.5 to 4.0 m tall and the stems are from 0.5 to 5 cm in diameter at the base. The seed is white, yellow or brown, usually 4-5 mm long and 2.5 to 4.6 mm wide.

The development of the plant takes 110 to 170 days, and is frequently considered to have three stages: emergence to floral initiation, floral initiation to flowering, and flowering to physiological maturity.

Some sorghum varieties contains tannins—bitter, stringent substances (polyphenols) in the undercoat that are distasteful to birds. However most varieties do not contain tannin.
and are, therefore susceptible to bird damage. There are a large number of pathogens that attack sorghum, for example Witchweed (Striga spp.), viruses, fungal diseases, etc.

Witchweed (Striga spp.) is a parasitic weed that attaches itself to sorghum roots from where it draws its moisture and nutrient requirements, inhibiting plant growth, reducing yields and in severe cases causes plant death. Some Striga-resistant sorghum varieties have been developed, but these generally offer lower yields than traditional cultivars and improved (but Striga-susceptible) varieties.

Grain moulds cause significant losses in both grain yield and quality, particularly in areas where improved cultivars have been adopted. Other important diseases include anthracnose, charcoal rot, downy mildew, ergot and leaf blight. Insect pests constrain production in many areas. Stem borers are endemic in all areas; head bugs and midges are most important in West Africa; and shoot fly causes substantial losses in late and off-season sowings in both Asia and Africa.

In the areas where sorghum is traditionally grown, plants may be attacked by as many as five or six pathogens.

3. Millets

3.1. History, Taxonomy, Distribution

3.1.1. History

Millets are a group of highly variable grasses with many small seeds. The most important millets are pearl millet (Pennisetum glaucum), finger millet (Eleusine coracana), proso millet (Panicum miliaceum), and foxtail millet (Setaria italica); other types of regional importance include fonio (Digitaria exilis), kodo (Paspalum scrobiculatum) and teff (Eragrostis tef).

The Pennisetum genus includes wild and cultivated types, with different geographic distributions, morphological similarities, and genetic differences. Domestication probably occurred 5000 or more years ago in the savannah south of the Sahara, and west of the Nile (Andrews and Kumar, 1992). Its introduction into India is believed to have been some 3000 years ago. It was cultivated in the USA by 1873, and probably came from Europe to USA. It has been grown in Europe since the end of the nineteenth century.

Seeds of the foxtail millet have been found in Neolithic sites (in eastern and central Asia, Europe, and the Middle East) suggesting that is one of the most ancient cereals domesticated in Eurasia. Setaria viridis is a probable ancestor.

Seeds of foxtail millet have been found in early sites in Switzerland and Austria dating back 3600 years and it was widely used as food during the Bronze Age. Finger millet is the second most important millet in Africa after pearl millet. It was domesticated in Africa some 3000 years ago and in the same period it was introduced into India. The wild ancestor of proso is likely to have occurred in Manchuria (de Wet, 1986) and these
wild forms spread into Europe (Ukraine, Czechoslovakia, Germany) and North America at least 3000 years ago (see Figure 4.)

![Proso or common millet](image)

**Figure 4: Proso or common millet**

### 3.1.2. Taxonomy

In recent times the cultivated pearl millet has been known taxonomically as *Pennisetum glaucum*, *P. typhoides* and *P. americanum*, but it is currently known as *P. glaucum* (L) R. Br. (Andrews and Kumar, 1992).

Hybrids of finger millet are between subspecies *Africana* and *coracana* form seeds and belong to race *spontanea*.

Millets belong to the *Poales* order and to the family of *Gramineae*.

### 3.1.3. Distribution

Pearl millet is the most widely grown of all millets, and it has the highest yield potential of all millets under drought and heat stress. The most important countries growing pearl millet are India, Niger, Chad, Mali, Tanzania, China and drier parts of the former
U.S.S.R. There are many other countries that grow the crop; it is sown on about 15 million hectares in Africa and 12 million in Asia (David A. V. Dendy, 1993).

Foxtail millet is found in Europe, China, India, Indonesia, the Korean peninsula and the former U.S.S.R.

Finger millet (it also adapted to temperate climates), known as ragi in India, is another important staple food in Eastern Africa and in Asia (e.g. India, Nepal).

Proso or common millet is grown in temperate climates. It is widely cultivated in the Russian Federation, the Ukraine, Kazakhstan, USA, Argentina and Australia.

Millets can survive in areas with as little as 300 mm or less of seasonal rainfall. The minimum water requirement is 400 mm for sorghum and 500-600 mm for maize.

Of all the millet varieties the pearl millet and proso millet have the largest grains.

3.2 Chemical composition (Carbohydrates, Proteins, Lipid, Vitamins and Minerals)

Millets are similar in composition and in nutritional value to rice (see Table 1)

3.2.1. Carbohydrates

The germ of pearl millet is a much larger percentage of the total kernel than is the germ of sorghum (17.4% in millet and 9.8% in sorghum). This difference explains in part the lower starch and the higher protein and oil contents of millet as compared to sorghum.

Starch represents about 56 to 65% of the kernel and is about 20 to 22% amylose; free sugars range from 2.6 to 2.8% of the grain.

The main sugar in pearl, foxtail, finger, and proso millets is sucrose.

Most of the dietary fiber of millets is insoluble Interestingly, α-amylase activity is 8 to 15 times greater in pearl millet than in wheat (Sheorain and Wagle, 1973).

The lysine content of pearl millet was 21% greater than corn and 36% greater than Sorghum.

3.2.2. Proteins

The protein content of pearl millet ranges from 8 to 19%, and there is better amino acid balance than in sorghum. Pearl millet is low in lysine, tryptophan, threonine and the sulfur-containing amino acids. Finger, teff, and kodo millets have similar amounts of lysine to pearl millet.
Fractions of protein in millets are as follows: albumins and globulins from 22 to 28%, prolamin and prolamin-like 22 to 35%, and glutelin and glutelin-like 28 to 32% of total N. The prolamin fraction in pearl millet is smaller than sorghum.

3.2.3. Lipid

The lipid content is generally high (3 to 6%) for pearl millet, higher than for sorghum and most other common cereals. For this reason the energy of millet is greater than that for sorghum and nearly equal to that of brown rice.

About 75% of the fatty acids in pearl millet are unsaturated, and linoleic acid is particularly high (46.3%).

After hulling or milling, the high lipid content, higher amounts of unsaturated fatty acids and high enzymatic-hydrolytic activity in millet products leads to rapid development of odors and flavors. The flour of millet becomes rancid rather rapidly.

3.2.4. Vitamins and Minerals

The vitamin content of pearl millet is not much different from sorghum. Dried, matured kernels do not contain vitamin C and the B vitamins are concentrated in the aleurone layer and germ. Removing the hull by decortication reduces the levels of thiamine, riboflavine and niacin by about 50% in the flour. Niacin in cereals is found in free and bound forms and can be synthesized from tryptophan. The niacin content of the hulled millet seed is still significant. This is why the PP vitamin insufficiency disease, pellagra, is not found in areas where millet is consumed in great quantities.

Malting and fermentation increase the amount of B vitamins and their availability.

The various mineral components of sorghum and millets grain vary widely, to a large extent reflecting the mineral composition of the soils and conditions where the plants are grown. In spite of this the total mineral (ash) content of all the millets is often higher than that of sorghum and other cereals.

Finger and teff millet are good source of dietary calcium. The percentage of available magnesium is higher in millet than in sorghum, and iron content is significant, too (see Table 2).

3.3 Anti-nutrients in millets

Millets have the following anti-nutrient components: polyphenols and tannin, phytic acid and phytate, goitrogens, and oxalic acid.

Millet changes color reversibly from grey to yellow-green at alkaline pH, and partially reversibly from grey to creamy white under acidic conditions due to the presence of phenolic compounds (glucosylvitexin, glucosylorientin, vitexin) (Reichert, 1979).
Polyphenols and tannin compounds are concentrated in the bran. Many of the millets contain tannins; varieties of finger millet tannin content are comparable to some brown sorghum. There is a strong relationship between the tannin levels and in vitro protein digestibilities.

Decortication significantly decreases the amount of tannins with a corresponding increase in protein digestibility.

Measurements have revealed 208 to 246 mg of phytic acid/100 g in finger millet, and the phytate content for proso millet was 0.17 to 0.47%. These values are higher than in rice. Dehulling of proso millets caused a 27 to 53% reduction in phytate content.

Pearl millet might be at least partly responsible for the higher goiter incidence in the Sudan. The goitrogen in pearl millet is a thioamide and/or other compounds derived from flavonoids; it is mainly found in the bran.

Goiter is due to the inhibition of the normal conversion of thyroxin to triiodothyronine.

Pearl millet, along with other grains, contains oxalic acid, which forms an insoluble complex with calcium, thereby reducing biological availability of this mineral. Calcium concentration in pearl millet is quite low, and the presence of oxalate can exacerbate the deficiency.

3.4. Use

The principal use of millet grain is for food (85%), with about 9% used for feed (N.L. Kent, 1975). Millet represents about 75% of total cereal food consumption in Niger and it is also a staple food in Namibia and Uganda, where millet is 25% and 20% of total cereal consumption respectively.

Millet is a high-energy, nutritious food, especially recommended for children, convalescents and the elderly. Several food preparations are made from millet; they differ between countries and even between different parts of a country.

Millet food products are similar to those of sorghum: thick porridges, thin porridges, steam-cooked products, fermented breads, unfermented breads, boiled rice-like products, alcoholic beverages, non-alcoholic beverages and snacks. However, because wholemeal quickly goes rancid (high fat content and hot climates) millet flour (prepared by pounding or milling) is stored only for short periods.

Millet is traditionally pounded in a mortar, but mechanical dehulling and milling are increasingly used since they eliminate a considerable amount of hard labor and generally improve the quality of the flour.

Pearl millet grown in USA is not used as a grain crop because of the low grain yields and because the plants are too tall for mechanical harvesting. Instead, the crop is used for animal feed.
In developing countries, use of millet grain for animal feed is concentrated in Asia; very little is used as feed in Africa. (It is estimated that less than 2 million tons of millet is fed to animals, compared with about 30 million tons of sorghum). Small quantities of finger millet are used in Zimbabwe for commercial brewing and opaque beer.

Couscous made from pearl millet has a darker color and stronger flavor but is better gelatinized than that from sorghum.

3.5. Agronomy, yield and production

Millets are better adapted than most other crops to dry, infertile soils, to high temperatures, low and erratic precipitation, short growing seasons and acidic soils with poor water-holding capacity.

Most millets have strong, deep rooting systems and short life cycles. Some species (particularly pearl and proso millets) can tolerate higher temperatures than sorghum and maize but they do not tolerate long drought periods as well as sorghum. Apart from grain production, millet is also cultivated for grazing, green fodder or silage. Pearl millet cultivars are often classified into late (130-150 days) and early (60-95 days) maturing groups. The early cultivars are insensitive to photoperiod and produce smaller plants (1.5 to 3 m tall). The late millets are photoperiod sensitive and produce tall plants (3 to 6 m).

The grain of finger millet is globular to oval, and has a diameter that ranges from 1.0 to 1.5 mm. The grain varies widely in colour. Foxtail millet is a short plant that grows and matures rapidly; it is ideally suited as a catch crop. The proso millet is a short plant that yields flattened kernels in a short time (60-90 days). Japanese millet is the earliest maturing of all millets (45 days).

In developing countries, mainly in Asia and Africa, almost all millet is produced by small-scale farmers for household consumption and local trade. These crops are usually grown without irrigation or chemical fertilizer, on light, well-drained soils that are poor in organic matter content. There is usually widespread Striga infestation, and downy mildew disease. Loss of grain to birds can also greatly decrease yield. Under different growing circumstances millet yields are very variable and usually much lower than yields of other cereals which are grown under more favorable conditions. In Niger, for example, average pearl millet yields fell from 510 kg/ha in 1988 to 240 kg/ha in 1990, then increased to 360 kg/ha in 1992.

The world’s major millet producers are shown in Figure 5.
Figure 5: The world’s major millet producers

Glossary

Kafirins: the major protein fractions in sorghum.
Dhurrin: the main cyanogenic glycoside in sorghum.
Hydrotermic technologies: flaked, puffed, extruded, micronized new products can be produced in special instruments, adding water, applying high temperature for an instant, applying or suddenly reducing high pressure. If applying hydrotermic technologies the raw materials almost entirely keep their nutritional value.
Cultivated: this implies that cereals have been adapted to the climatic and growing conditions of a specified area under more or less controlled cultivation practices.

Bibliography


Ottawa. Ont. IDRC. 1979. pp. 64 (This paper discusses methods of harvesting, drying milling, grain processing, use, food production, marketing of sorghum and millets, includes a lots of sorghum and millet foods recipes.)

**To cite this chapter**