

# Pearl Millet—New Developments in Ancient Food Grain

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Millets are collectively the world's sixth most important cereal, with an annual production of around 30 million tons (11). There are many species that are called millets. However, pearl millet (*Pennisetum glaucum*) (Fig. 1a) is by far the most important millet, accounting for about half of total millet production. Pearl millet grain is ovoid- to tear-shaped and somewhat shiny in appearance with a creamy white, gray, or purplish color (Fig. 1b). It is so named because of its resemblance to seed pearls. The grain is about one-third the size of wheat. Despite its small grain size, pearl millet has relatively good nutritional value compared to other cereal grains. This is on account of its proportionally large germ compared to endosperm. The average fat content is around 5.1%, with linoleic acid (C18:2) accounting for some 44% of total fatty acids (9). These values are very similar to maize, approximately 5.3% and 44%, respectively (13). The average protein content of pearl millet (14.5%) is considerably higher than maize's (10.5%). Also, the protein is somewhat richer in lysine, the first limiting indispensable amino acid, 3.3% compared to 2.8%. As pearl millet is closely related to maize and sorghum, it is "gluten free."

## Ancient Grain and Modern Day Cultivation

Pearl millet was first domesticated in Africa some 5,000 years ago (1). It is a uniquely hardy crop cultivated in regions



- How is pearl millet, an ancient hardy grain, becoming an important cash crop in arid regions around the world?
- How are entrepreneurs in Africa making value-added food products from pearl millet for the newly urbanized population?
- This article discusses the applicability of these pearl millet products to ethnic and health food markets across the world.

with very high daily average temperatures, up to about 30°C and very low annual rainfall, down to 250 mm (7). In Africa, pearl millet is extensively cultivated across the western side of the continent from the Sahel (Sahara Desert margin) in West Africa, down to Namibia and South Africa and the eastern side of the Sahara desert from Sudan into East Africa. It is also an important crop in the dry sandy areas of India, such as Rajasthan and Gujarat.

In Africa and India, pearl millet is almost exclusively cultivated by smallholder farmers and has up until very recently been regarded as a subsistence crop. However, because of its hardiness, pearl millet is becoming a commercial crop in other arid regions of the world, for example, in the state of Georgia (Fig. 1c) (5), Australia, and Brazil (Fig. 1d). In the southeastern United States, it is grown on nearly

three million hectares as a forage crop because of its disease resistance. Varieties grown in Georgia are for special use in foods, pet foods, and related products. Production is grown under contract and the grain is harvested at high moisture and then dried to avoid discoloration. Pearl millet is grown in Brazil on the dry prairies where it is a preferred part of the cropping systems used on these special soils. It provides the necessary soil amendments to improve soybean production significantly.

Africa is urbanizing rapidly. In the 50 years since 1960, the percent of Africans living in urban areas has more than doubled from 18 to 40% (12). The percent increase of urban dwellers in North America was much smaller (69 to 78%). The rapid increase of urban people in Africa is expected to continue, with a doubling in number by 2030. The United Nations

doi:10.1094/CFW-55-1-0016  
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Population Fund sees the rapid urbanization in Africa and Asia as “unleashing the potential for growth.” In the context of cereal foods, urban families are often away from home and do not have time to prepare traditional meals starting with milling grain to flour. However, they like the traditional foods they were brought up on and will pay for convenience and quality combined with tradition. This paradigm shift is creating a demand for the commercial manufacture of innovative value-added cereal food products by entrepreneurs, including many made from pearl millet (14). Millet production in Africa is increasing substantially. From 1982 to 2007, millet production (mainly pearl millet) rose from 7.6 to 17.2 million metric tons (4). This growth is continuing and now modern agricultural practices are being applied as it becomes a commercial commodity. For example, in 2009, some 1,700 hectares of new technology plantings using improved millet and sorghum cultivars are taking place in Sahelian countries, according to John Sanders, agricultural economist, Purdue University.

This article describes new developments in pearl millet food products in Africa that also have potential in other parts of the world. Two levels of value addition can be distinguished: flour products (the more basic) and ready-to-eat (RTE) foods. Examples of each will be described below.

## Flour Products

### Milling

In Namibia, pearl millet is the most important staple cereal food grain (3), where it is known as *mahangu*. Pearl millet flour is made into thick porridge (*oshifima*), thin porridge (*etete*), pancakes (*omungome*), and even cake (*oshikwila*). Traditionally, people in Namibia prefer pearl millet flour with a slightly sour flavor, resulting from lactic fermentation during milling. As will be seen, acidic pearl millet foods are popular across Africa.

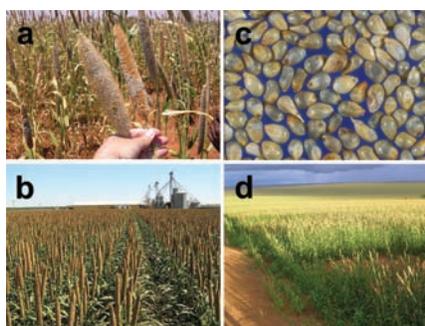
In the traditional milling process, the grain is conditioned with water and deb-

ranned using a wooden mortar and pestle. The debranned grain is steeped for one to two days at room temperature in water, allowing lactic acid fermentation. This fermented grain is partially dried in the sun (10), milled into flour using a mortar and pestle, and then the flour is dried in the sun prior to storage.

Today, commercial millers use locally made abrasive disk dehullers to debrann the pearl millet grain (Fig. 2a). This type of dehuller was originally developed by the Canadian Prairie Research Laboratory (2) to debrann barley and oats. The debranned pearl millet is then steeped (Fig. 2b) and partially dried (Fig. 2c), and the damp grain is milled into flour using hammer mills (Fig. 2d). The flour is then sun dried and bagged for sale (Fig. 3a).

Thus, traditional pearl millet milling is both laborious and inefficient. Today in Namibia, pearl millet flour is also produced by large-scale industrial milling. The grain is mechanically debranned by abrasion, essentially as described above. This product is sold as pearl millet rice. To produce flour, the “rice” is milled by roller milling, sized, and purified using plansifters and purifiers from wheat milling equipment.

Table I gives the physical and chemical composition of pearl millet flours pro-



**Fig. 1.** Pearl millet. a) experimental farm in Kenya showing resistance of bristled type head to bird predation (left) versus normal type (right); b) grain of variety SDMV 89004 developed in Zimbabwe; c) under cultivation in Georgia (U.S.A.); and d) under cultivation in Brazil (courtesy of Jeff Wilson, USDA).

duced by both processes. Although the proximate composition of the flours is similar. Notably, the flour produced by the industrial milling process is darker in color and higher in total polyphenols and n-glycosyl flavones than the traditionally produced flour. This can be attributed to its slightly higher extraction rate resulting in the flour containing more of the pericarp where the phenolics are concentrated, and to the absence of the steeping process where some of the phenolics would be



**Fig. 2** Traditional mahangu (pearl millet) milling in northern Namibia. a) PRL type dehuller; b) steeping (lactic acid fermentation) vessels; c) sun drying the fermented grain; and d) hammer mill.



**Fig. 3.** Pearl millet flour products. a) traditional produced flour from Namibia; b) industrially produced pure pearl millet and composite pearl millet-maize flours from Namibia; c) composite presoured uji flour from Kenya; d) flour from Mali; and e) semolina from Senegal.

**Table I.** Effects of the traditional semiwet and industrial dry milling processes on the physical and chemical composition (dry basis) of pearl millet flours<sup>a</sup>

Sample	Flour extraction rate (%)	Color (N x 6.25) (L)	Protein (g/100 g)	Ash (g/100 g)	Carbohydrate (starch) (g/100 g)	Fat (g/100 g)	Total polyphenols (mg/100 g)	C-glycosyl flavones (mg/100 g)
Whole grain	100	53.3 a	14.8 c	1.6 c	4.86 c	59.8 a	150 c	118.0 c
Traditional hand-pounded and hammer-milled fermented flour	88.1	76.5 c	13.2 a (89.2)	0.76 a (46.3)	3.84 a (79.0)	70.8 b (118)	80 a (53.4) q	60.7 a (51.4)
Industrially roller-milled flour	92.7	74.8 b	13.4 b (90.5)	1.12 b (68.3)	4.08 b (84.0)	69.8 b (117)	140 b (93.3)	64.8 b (54.9)

<sup>a</sup> Figures in columns with different letter notations are significantly different at P < 0.05. Figures in parentheses are percentages of whole grain composition.

leached out. The industrially milled flour also lacks the traditional sour flavor.

#### Enriched Flours

Industrially milled pearl millet flour is marketed as a product by itself and as a composite with maize flour (Fig. 3b) for making porridge. Composite pearl millet and wheat flours have applications in pasta, bread, biscuits, and other bakery products. A commercial process for making the traditional pearl millet cake, “*oshik-wila*,” with added marula oil has been developed. In Senegal, composite wheat breads containing pearl millet flour are quite popular in many small bakeries.

In Kenya, pearl millet is composited with a variety of other cereal flours, including finger millet, sorghum, and wheat in commercial flour products for making *uji* (thin porridge) (Fig. 3c). The KenUji product shown is particularly interesting in that a souring agent, a fruit acid, is included in the ingredients. The purpose of this is to give the porridge an acidic flavor, mimicking the traditional lactic acid flavor, but without the need for fermentation.



**Fig. 4.** Ready-to-eat pearl millet products. a) instant tamarind-flavored gruel from Nigeria; b) couscous from Senegal; c) couscous from Senegal; and d) thiakri millet and yogurt from Senegal.



**Fig. 5.** Pearl millet couscous manufactured in Senegal. a) dehuller; b) steamer; and c) agglomerating and sifting the couscous.

Figures 3d and 3e show pearl millet flour and semolina products from Mali and Senegal, respectively. The former is packaged in a polyethylene bag for local sale, whereas the latter is in a cardboard carton with elegant labeling and is aimed at the gluten-free market in Europe.

Since pearl millet grain cannot be imported into the United States, there is a large niche market for similar products from people who were originally from the Indian subcontinent. Pearl millet is often preferred by Indians and Pakistanis who grew up consuming it in a wide variety of foods, including flatbreads (roti, chapattis), parched or expanded grains, “rice,” and porridges. The varieties of pearl millets preferred are quite dark in color. These could be grown in the United States and the relatively high value of the products make it an attractive crop to consider.

#### RTE Foods

RTE pearl millet flour products are substantially less common than enriched flours, probably because the technology is more sophisticated and they are more expensive with a much smaller market. In Namibia, there is a pearl millet-sorghum instant flour product for making the traditional millet beverage called *oshikundu*. Figure 4a shows a similar extrusion-cooked instant flour from Nigeria for making an RTE version of the traditional Nigerian pearl millet porridge *kunun tsamiya*, which literally means “gruel of tamarind.” The product is flavored with tamarind oil, another example of an acid-flavored African pearl millet food.

In the Sahel region, couscous made from pearl millet and sorghum is a very popular, traditional staple food. Commercially produced millet and sorghum couscous products from Senegal aimed at the upscale local market and created for export to Europe are shown in Figures 4b

and 4c, respectively. The commercial process of making sorghum and millet couscous involves decorticating the grain with an abrasive dehuller (Fig. 5a). This particular type of dehuller is specially developed for pearl millet in that the bran is removed by revolving brushes rather than aspiration, as in the type shown in Figure 2a (2). The revolving brush system reduces losses of fine-grain particles. Thereafter, the grain is milled into flour with a hammer mill. The couscous is produced from the flour by repeated agglomeration, steaming (Fig. 5b), and sifting of the particles to a uniform size (Fig. 5c) (6). Attempts have been made to mechanize the agglomeration and sifting process but they have not been widely implemented.

A very innovative and popular commercial product produced in Dakar, Senegal, is yogurt containing millet couscous (Fig. 4d). This product is based on a traditional, soured, custard-like product in the Sahel region called *thiakri* (*thiacry* or *tiakri*), and is another example of the diverse acidic-flavored Africa pearl millet foods. The production of yogurt has spread to many West African countries where pearl millet or sometimes sorghum couscous or other cooked agglomerated products are used in RTE products. These products have excellent flavor and their quality is consistent. Several small processors are involved and have developed supply chain management systems to obtain good quality grain for processing. This is essential if high-quality products are going to be produced, since the pearl millet can have 10–20% impurities, including sand, etc. Excellent progress is being made by working with farmers, suppliers, and processors to secure and pay for high-quality grains.

Perhaps the most interesting RTE pearl millet-based food product that the authors have come across is instant weaning porridge, made in Ouagadougou, Burkina Faso (Fig. 6a). Pearl millet and maize are first debranned and then milled into flour. Two alternative processes are then used to precook the flour. In one process, stiff dough is first made by mixing flour and water. The dough is then baked using a continuous oven originally designed for making cookies (Fig. 6b). Alternatively, a small extrusion cooker is used (Fig. 6c). The “cookies,” or extrudate, are milled into flour and a vitamin and mineral premix is blended in.

To illustrate one of the problems that small entrepreneurial food manufacturers in Africa face, we refer to a similar product composed of decorticated pearl millet and cowpeas that was produced commercially in Mali during the mid 1980s. It too was sold as a weaning food for children



**Fig. 6.** Commercial instant pearl millet and maize infant food manufacture in Burkina Faso. a) infant food product; b) cooking the dough with a continuous oven; and c) a small extruder for cooking the flour.

and was successful but it could not compete with imported products because of inadequate supplies of grains of suitable quality for processing. The millet and cowpeas had very high levels of impurities that also drove up the price.

### Concluding Remarks

This article shows that across Africa, pearl millet is moving from a subsistence grain to an important ingredient in a wide range of added-value competitive “ancient grain” food products, which could find valuable niche markets in other parts of the world as health and ethnic foods. Unfortunately, there are still several obstacles hindering this important economic development. Although millet production is increasing in Africa, crop yields remain very low, on average only about 700 kg/ha (4). This is attributed to poor agricultural practices, slow adoption of improved varieties, and crop losses due to biotic stresses, including birds (Fig. 1a, right). There is also a “chicken-and-egg” situation. Farmers will not spend money to improve productivity unless there is a profitable market for their grain. At the same time, entrepreneurs will not use pearl millet as an ingredient unless there is a constant supply of reliably quality grain available at an economical price. Thus, the lack of pearl millet for processing in large quantities is a major disadvantage of this unique ancient grain. The solution to this seems to be the application of a supply chain management strategy, whereby all the constraints from “farm to fork” are addressed in a coordinated manner (14). Application of this strategy, including the cultivation of improved cultivars, use of inorganic fertilizers, simple post-harvest grain handling techniques to produce clean grain, and sound grain market practices, have resulted in dramatic increases in sorghum and millet yields and profitability for farmers in countries, such as Mali, Niger, and Senegal (8).

### Acknowledgments

The authors wish to thank the Sorghum, Millet, and Other Grains Collaborative Research Support Program (INTSORMIL) for funding part of this work and the proprietors of the Jaboot (Dakar) and Sodepal companies (Ouagadougou) for kindly hosting us and permitting us to take photographs.

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