The Utilization of Sorghum: A World Review

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Resumen: El sorgo es el principal cereal en muchas áreas de Africa y Asia. Cantidades significantes de este cereal son usadas para consumo humano y uso industrial en otras partes del mundo. El principal uso del sorgo en el hemisferio occidental es como alimento para ganado. Las principales categorías de alimentos tradicionales de sorgo y los tipos de sorgos deseados para cada clase de alimento son discutidos. Los principales usos industriales del sorgo son brevemente descritos. La meta de los fitomejoradores de sorgo deben ser el de desarrollar granos con pericarpio blanco, plantas con color claro, y granos con endospermo de textura intermedia o córnea. Un sorgo con tales propiedades tendrá magníficas cualidades para alimentación animal o humana así como también para uso industrial.

ABSTRACT

Sorghum is a major food grain in many areas of Africa and Asia. Significant quantities are used for food or industrial processing in other areas of the world. Its main use in the western hemisphere is as a livestock feed. The major categories of traditional foods made from sorghum and the types of sorghum desirable for each class of food are discussed. Major industrial uses of sorghum are briefly described. The goal of sorghum breeders should be to develop a white pericarp, tan plant color with intermediate to hard endosperm texture. Such a sorghum would have outstanding properties for livestock feed as well as for food and industrial processing.

INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) is one of the five most important cereal grain species that man depends upon as a food grain. Figures on the proportion of world sorghum production used for human food directly are hard to document. It is commonly observed that 50% or more of the total production

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is eaten directly. This means that there are huge areas where the sorghum grown must have critical food quality attributes to meet the needs of traditional food systems. The objectives of this presentation are to review the traditional uses of sorghum for food worldwide and describe the desirable attributes required for sorghums with acceptable food quality in so far as we know the traits.

TRADITIONAL FOOD SYSTEMS

Significant progress has been made to define traditional sorghum food systems and to determine the critical attributes of sorghum that affect its processing quality (Rooney et al., 1986). Table 1 contains a summary of the major traditional food systems, a brief description of the processes and various names for the foods. Each dialect or tribal group usually has a name for each food system, therefore, scores of names exist for similar products. The classification schemes have facilitated our understanding of sorghum quality attributes as they relate to the general food categories.

CHARACTERISTICS OF SORGHUM FOR TRADITIONAL FOOD QUALITY

Progress has been made in relating the general physical and structural properties of sorghum to the major categories of traditional food products (Rooney and Murty, 1982a, 1982b). The structure of the grain has an important bearing on various processing and food quality traits (Hoseney et al., 1981; Rooney and Miller, 1982; Rooney et al., 1986; Rooney and Pflugfelder, 1986). Shape, size, proportion, and nature of the endosperm, germ, and pericarp; presence or absence of subcoat; and color of the pericarp are all genetically controlled (Rooney and Miller, 1982).

Endosperm texture, i.e., the relative proportion of hard to soft endosperm, plays a major role in determining the quality of traditional sorghum foods (Rooney and Murty, 1982a, 1982b; Cagampang and Kirleis, 1984).

In sorghums with a higher percentage of corneous endosperm, the pericarp (bran) is more readily separated from the

Table 1. Traditional foods made with sorghum.

Common Name	Countries	Description
Unfermented bread		
chapati *roti* *rotti*	India	Flour (95 to 100% extraction) is mixed with water and kneaded into a dough. The dough is then formed into a thin circular piece about 20 to 25 cm in diameter. The dough piece is cooked on a hot grill at 210°C for 25 sec. Then the outside is sprinkled with water; the dough piece is turned over and cooked for 25 sec. or until it puffs. Sorghums differ in extent of puffing, texture, color, taste, and keeping quality. Whiteseeded sorghum makes the best *chapati*.
tortilla	Central America, Mexico	A 3:1 ratio of lime solution to sorghum grain is cooked for 15 to 40 min. at the boiling point. The lime solution contains 0.8% lime based on grain weight. The cooked sorghum is cooled, washed with water to about 8.5 pH, ground into *masa*, and pressed into *tortillas*. The *tortilla* is cooked on each side for 30 sec. at about 210°C on a grill. Sorghum *tortillas* are off-colored compared to those made with white maize. Usually mixtures of maize and sorghum are used.
Fermented bread		
kisra	Africa	Whole sorghum is ground into a fine flour. A starter, which contains a combination of yeast and lactobacillus (usually obtained by saving part of the last batter), is mixed with water and flour to form a paste, which is fermented overnight. The fermented batter is thin enough to spread in a thin layer on the surface of a hot griddle. The *kisra* is cooked for about 30 sec. and removed from the grill. Good *kisra* is paper thin with a sour taste and fermented flavor.
dosa *dosai*	India	
injera	Ethiopia	Whole sorghum flour is mixed with about 40% of the total water and inoculum. Usually starter from a previous batch is used. The mixture is kneaded into a dough, which is fermented overnight. Then about 10% of the fermented dough is mixed with water and cooked. The cooked material is added to the remaining dough and water. The batter is allowed to undergo vigorous fermentation for 2 hr; then it is poured in a thin layer onto a hot griddle and baked. *Injera* is a large, thin layer with a very soft texture and numerous "fish eyes" on the surface. *Injera* batter is thicker than that of *kisra*.

Table 1 (Con't). Traditional foods made with sorghum.

Common Name	Countries	Description
Stiff porridge		
aceda *nuchu* *asidah* *sadza* *atap* *saino* *bogobe* *ting* *dalaki* *tô* *kalo* *tuo* *karo* *tutu* *kwon* *tuwo* *mato* *ugali* *nshimba* *zaafi*	Africa India	Decorticated sorghum flour is stirred into boiling water until a very stiff paste is formed. The paste is stirred vigorously while it is cooked. The porridge is placed in a calabash (gourd), cooled for 1 hr, and eaten with a sauce. Sometimes acid or base is mixed into the cooking water. In Burkina Faso, tamarind pods are steeped overnight in the cooking water. In Mali, alkali is added to the cooking water. Soured fermented porridges are common in most countries. Granulation of the flour, composition of the sauce, and consistency vary among countries and tribes within a country.
Thin porridge		
ambali *atole* *edi* *eko* *kamu* *nasha* *obungi bwa kal* *obushera* *uji*	Africa India Mexico Central America	Decorticated sorghum flour in cool water is mixed into boiling water with stirring until a thin paste is formed. The consistency is similar to that of cream. It is made with acid or alkali in the cook-ing water. Sometimes a part of the flour is fermented 24 hr. before cooking. Particle size varies. Flour is made from sprouted grain, pearled grain, or whole grain. The porridge is served with milk, sour milk, sugar, honey, fruit, and other variations, depending on local preference.
akamu *akasa* *kafa* *koko* *ogi* *oko*	Nigeria Ghana	Sorghum grains are steeped in water for two to four days at room temperature. The fermented grain is milled, and the bran is removed by screening. The sediment in the pot is cooked in water to produce a porridge that is consumed warm or cooled to form a gel or pudding. It is preferred as a weaning food and for elderly people.
Boiled whole or pearled		
acha *kali* *mudde* *sankati*	Africa India	Sorghums are pearled to remove the pericarp and cooked like rice. Usually in India, special varieties of sorghum with a high proportion of corneous endosperm are preferred. Whole grains are sometimes boiled, parched, or steamed and consumed with legumes or a sauce. Sorghum is mixed with rice as an extender.
Snack foods	Worldwide	Sorghums are popped, puffed, and parched. They may be consumed directly or ground and mixed with other ingredients. Fried snacks are popular. There are numerous variations in snacks.

Table 1 (Con't). Traditional foods made with sorghum.

Common Name	Countries	Description
Steamed cooked product		
couscous	West Africa	Finely ground sorghum or millet flour is kneaded with water until the flour particles agglomerate. Then the particles are forced through a coarse screen. The particles are placed in a container with a perforated bottom, which is placed on top of a pot filled with boiling water. Steam penetrates through the agglomerated particles. Several times during cooking, the *couscous*, is removed from the pot, stirred, sieved, and returned to the cooker. Usually ground baobab leaves, peanut butter, okra, or some other additive is mixed with the *couscous* during the final steaming. The cook-ed product is consumed with a sauce. Sometimes it is dried, stored, and used as a convenience food.
Alcoholic beverages, sweet/sour opaque beers		
burukutu *dolo* *pito* *talla*	West Africa	Sorghum is steeped, germinated, and dried. Mash is prepared by mixing the ground malt with water. The mixture is filtered to remove the bran. The wort is boiled, cooked, and inoculated with yeast from a previous batch of beer. Fermentation occurs overnight, and actively fermenting beer is drunk the next day. Beer is a relatively clear red liquid with a sweet pleasant taste and low solids content. Continued fermentation produces a sour taste. The beer is about 1 to 5% alcohol.
Sour/opaque beers		
banutu beer *busaa* *chibuku* *ikigage* *kaffir beer* *marisa, merrisa* *munkoyo* *mwenge* *sorghum beer* *urwaga, utshwala* *utywala*	Sudan Southern Africa	Ground sorghum malt is mixed with water, allowed to sour, boiled with adjunct (corn grits), cooled to 60°, and saccharified with more sorghum malt. Maize grits are often unavailable, so sorghum is used in many areas. The mixture is filtered to remove the larger particles and fermented with top-fermenting yeast. Beer has a high solids content with a sour taste and bright pink color. It has the consistency of a milk shake. The alcohol content depends on fermentation time and ranges from 1 to 8% by volume.
Nonalcoholic beverages		
amaheu *leting* *magou* *mahewu* *marewa*	Africa	Ground sorghum, sometimes mixed with sprouted sorghum, is held at elevated temperatures for up to 20 hr. Lactobacilli and other microorganisms cause souring of the mixture. Very little alcohol is produced. Sour nonalcoholic beverages have lower dry matter contents than sour thin porridges.

endosperm, thus, giving a higher yield during dry milling. Insects more readily attack sorghum with a soft, floury endosperm than one with a harder corneous endosperm. The particle size, amount of starch damage, and other important factors relating to food quality of sorghum are related to endosperm texture and the way the endosperm breaks during milling. For example, the grittiness of some sorghum flours is due in part to intact cells from the peripheral and corneous endosperm.

Several interacting factors influence the color of sorghum kernels as viewed by the eye; these are pericarp color, pericarp thickness, presence of a testa, and color and thickness of the testa (Rooney and Miller, 1982). Genetically, sorghum pericarp color is only red, white, or lemon yellow. Plant and glume color affect the expression of pericarp color. When the pericarp is white and the plant color is tan, the kernel appears much more white than the same kernel does when it is on a red or purple plant. The presence of a pigmented testa and the distribution of tannins in the pericarp is genetically controlled and affects kernel appearance and quality significantly. Additional color modifications are induced by differences in endosperm color (yellow, white), texture (corneous, floury) and type (normal, waxy, or sugary). Corneous textured endosperms give more brilliant colors, and floury textures give more dull or opaque colors. A thick pericarp gives a dull or chalky appearance.

The kernel characteristics of sorghum that are currently thought to be most desirable for use in each class of traditional foods are presented in Table 2. These desirable traits are based upon the collective experience of scientists who participated in the International Sorghum Food Quality Trials (Rooney and Murty, 1982b). In general, the property of sorghum that affects its quality most consistently is endosperm texture. Thus, three classes of sorghum based on endosperm texture have been proposed: 1) hard--suitable for rice like products, thick porridges and *couscous*, 2) intermediate--unfermented breads, malting and brewing, and 3) soft--fermented breads. Therefore, plant breeders selecting for food quality within a specific type of food category should select visually for certain kernel characteristics and texture. In general, within each hardness group or class, the preferred sorghum has white pericarp without a pigmented subcoat and tan plant color. The quality of sorghum

Table 2. Kernel characteristics of sorghums desirable for making traditional foods.

Food Products	Milling[†]	Pericarp Thickness	Pericarp Color	Testa	Plant Color	Endosperm Texture
Unfermented breads						
chapati	WG	thin	white	none	tan	intermediate
tortilla	WG	thick	white	none	tan[‡]	intermediate
Fermented breads						
kisra	WG	thick	white	yes[§]	NP[¶]	soft, floury
injera	D	thick	white	none	NP	soft, floury
Stiff porridges	D	thick	white	none[#]	NP	corneous
Thin porridges	D	thick	white	none[#]	NP	corneous
Steamed products	D	thick	white	none	NP	corneous
Boiled sorghum	D	thick or thin	white	none	NP	corneous
Beer	WG	thin	red	yes[††]	NP	intermediate

[†] WG=Whole grain, D=decorticated.

[‡] Sorghums with purple plant and colored glumes are used currently in Central America. Thus significant improvement in sorghum quality for *tortillas* is possible.

[§] Sorghums with a testa are widely grown and used for *kisra* and *injera*. Color is not the most important criteria.

[¶] NP=No preference.

[#] Local types with thin pigmented testa are grown and used for tô.

[††] Sorghums available for local brewing often have pigmented testa with dominant spreader gene present. For industrial brewing, red sorghums without a pigmented testa are best.

for use in each of the traditional foods is absolutely critical. This has been learned the hard way in breeding programs in Africa and India.

Not all sorghums used for food are white. In many areas, brown sorghums are produced and consumed. In the Sudan, most of the native feterita types of sorghum have a pigmented testa. Though some Sudanese prefer white sorghums, those with pigmented testa are consumed in *kisra*. The viscosity of the batter and flexibility of the *kisra* are major attributes. The presence of a soft endosperm is highly desirable. The low pH of the process improves the color of products made with pigmented sorghums.

Sorghums used in traditional brewing are in general brown with B_1, B_2, and S genes even though red sorghums without a testa are preferred. These brown grains are used because they often yield more grain and are less preferred for other food uses. They are utilized in traditional brewing, although, they are not suitable for industrialized malting or brewing. In South Africa, a formal program to evaluate malting quality of sorghum is rigorously pursued (Novellie, 1985). The brown sorghums are lower priced than other sorghums, and premiums are paid for red sorghums without a pigmented testa which possess good malting quality.

Generally, the brown bird-resistant sorghums are undesirable for traditional food systems. However, they are often grown where birds and grain molds are major problems. Special processes have been used to convert the brown sorghums into foods. In some areas, the brown sorghums are steeped in wood ashes, germinated, and used to produce thick porridges. Sometimes special porridges made from brown sorghum are given to new mothers or are consumed by farmers doing strenuous work. Brown sorghum porridge is said to stay with the farmer longer, possibly because the condensed tannins affect digestibility (Butler, 1982). Considerable progress has been made in the last decade in defining sorghum properties that affect its quality for traditional food systems. However, additional work is needed to develop selection procedures for each major kind of food.

INDUSTRIAL PROCESSING & UTILIZATION OF SORGHUMS

Sorghum can be and is used for a wide variety of industrial and food products. Several applications will be discussed. All of those require a consistent supply of high quality sorghum and could benefit from improved sorghum quality.

Beer

Sorghum beer in Southern Africa is made on a very large scale in modern high capacity breweries. The industry includes germinating sorghum to produce malt with desirable enzymatic activities, flavor and modifications of the sorghum kernel. Then, the malt is milled and soured and allowed to undergo alcoholic

fermentation. The thick, opaque, light pink actively fermenting beer is sold in small cartons to consumers or in bulk tankers to beerhouses.

Chibuku or sorghum beer contains 2 to 4% (W/V) alcohol, 0.3 to 0.6% lactic acid and 4 to 10% total solids with a pH of 3.3 to 3.5. The beer is an important source of nutrients in many areas because it contains vitamins, minerals, proteins and carbohydrates that have been solubilized during malting and brewing (Novellie, 1977, 1982). In some areas, the production of *chibuku* beer is decreasing as consumers become more affluent and desire European lager type beer. Nevertheless, the sorghum beer industry is of major significance as an industrial user of sorghum.

Sorghums with bright red pericarp without testa with an intermediate hardness are preferred for brewing. High tannin sorghums are undesirable for industrial production of *chibuku.*

European Lager Beers

Sorghum is often used as an adjunct in brewing barley beers. The adjunct serves as an inexpensive source of fermentable carbohydrates. Up to 40% sorghum grits are used. Sorghum grits for brewing should have light color, bland flavor with good cooking/mashing properties. Sorghums used today are red U. S. type hybrids; but, the use of white, tan plant hybrids with improved milling properties would be a significant improvement. The brewing industry in Mexico has successfully used sorghum for more than 20 years. Brewing properties of waxy endosperm sorghum grits might be an advantage; but, it has not been tested apparently.

Sorghum Lager Beers (without barley)

In certain African countries, the government has decreed that imported barley or malt cannot be used in beer. Therefore, brewers may be forced to produce beer from indigenous cereals especially sorghum. A delightful lager beer can be made from 100% malted sorghum, but, it does not look or taste like barley beer. If these restrictions against barley importation are put into

effect, sorghum hybrids designed for beer production will be needed. Probably, the bright red sorghums useful for traditional sour opaque beers will be used.

Baked

Sorghum flour can be substituted for 5 to 100% of wheat flour for baked products depending upon the particular food system; the strength of the gluten in the wheat flour and specific baking procedures. Some countries are legislating that certain levels of sorghum flour be substituted for wheat flour. The tan plant, white food type sorghums produce bland flavor, reduced color flours for these applications. Good cookies or biscuits with 100% sorghum flour have been baked. Generally, sorghum causes the texture of baked products to be drier and gritty so adjustments to the formula are required.

Breakfast Foods and Snacks

Sorghums have been puffed, popped, flaked, shredded and extruded to produce excellent prepared breakfast cereals and snacks in the U.S.A. and other countries. The white food type sorghums produce bland, light colored products that can be artificially flavored and colored. The bland taste is an advantage for sorghum over maize for some applications. For example, consumers who do not like the taste of maize may find snacks from sorghums acceptable provided the sorghum has acceptable food properties. Several commercial breakfast foods are sold in some areas of Southern Africa. In India, a wide variety of snack foods made with sorghum and blends of sorghum with other cereals and legumes are popular. Weaning foods using malted sorghum have been developed in India as well.

Livestock Feed Processing

The largest industrial use of sorghums is in livestock feeds, especially in feedlots in the U.S.A. where sorghum is processed using sophisticated methods involving steam-flaking, popping, micronizing, puffing or exploding, and reconstituting (Rooney and Pflugfelder, 1986). These processes are used to produce rations for 200,000 cattle in a single feed lot. In general, feedlots have found that yellow endosperm and white sorghums have steam flaked more efficiently than red sorghums. A white waxy sorghum would have excellent potential for processing via steam

flaking. The white, tan plant grains generally have excellent processing properties also.

Dry Milling

Most of the industrial utilization applications are based on the milling of sorghum to produce grits, flour and meal free of bran and germ contamination. The millability of sorghum is affected by kernel size, shape, hardness, pericarp thickness and color, and the plant color. For dry milling, sorghum with tan plant, white pericarp, spherical kernels and a high proportion of corneous endosperm are most desirable. Grain with those characteristics give the highest yields of endosperm fractions with the least color. Sorghums that produce these types of dry milled products in high yields are essential for development of breakfast food, adjuncts for beer, snacks and baked products.

Sorghums for Feed

Sorghum will continue to be used mainly as a feed in many areas of the world especially in Mexico and Central America. White sorghums that have acceptable food properties certainly have excellent feeding properties as well. The feeding value of white sorghums may in fact be slightly better than that of red sorghums. The fact that most sorghums used for feed is red is only a reflection of the fact that the seed companies have not spent sufficient time to develop acceptable white hybrids.

There are no advantages for the production of red sorghums for use in feeds. In fact, for many feed applications a white grain with yellow endosperm would produce the best feed in terms of its appearance. Many feeders prefer the color of feeds containing corn over the dark brownish red color of feeds containing brown or red sorghums. For example, Korean feed manufacturers often limit the quantity of sorghum in feed formulations to a maximum of 15 to 20% to avoid production of dark colored feeds.

A super feed sorghum would have a tan plant, white pericarp with a harder kernel that would also be more useful for industrial and food processing. The goal of most plant breeding programs should be to develop sorghum cultivars and hybrids with the widest possible utilization characteristics. In that way, sorghums with useful properties will be available to potential processors.

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