Overcoming Constraints to Utilization of Sorghum and Millet

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Abstract

Sorghum and pearl millet are used in a wide variety of traditional foods in the semi-arid tropics. However, their use as food is declining in urban areas as wheat, rice, and maize products become more plentiful. Lack of a reliable supply of high quality grain for processing severely limits the acceptance of sorghum and pearl millet. Shelf-stable products are in short supply because the grains available for processing are of inferior quality. Technology is available for processing sorghum and pearl millet; however, major extension and improved cultivars are needed. Other constraints to the use of sorghum and pearl millet include their image as "second class" crops, the tannins in sorghum, low cost imported wheat, rice, and maize, and government policies. Breeders must work diligently to develop new cultivars, targeting total units of useful food or feed per hectare. Improved end-use quality will allow value-added processing, which could improve farm income from identity-preserved grain.

Sorghum and pearl millet are important food crops in the dry tropical areas of the world. They have good composition and can be made into a wide array of products, such as fermented and unfermented breads, beverages, porridges, snacks, rice-like products, and couscous. Significant reviews on the chemistry, quality, nutritional value, and technology of sorghum and millets have been published (Hulse et al., 1980; Rooney et al., 1980, 1982, 1986; Hoseney et al., 1987; Rooney and Serna-Saldivar, 1991; Serna-Saldivar et al., 1991; Dendy, 1995).

The purpose of this paper is to critically evaluate the major constraints to sorghum and millet use and to determine what can be done to enhance and expand use of sorghum and millet because of their relative advantages in hot dry environments. We do not intend to review all the literature, but we have included a bibliography of critical references.

Constraints on the Use of Sorghum and Millet as Food

Use of sorghum and millet as human food has decreased during the last two decades for many reasons. Lack of a consistent supply of good quality grain for processing is a tough obstacle to overcome. The image of sorghum and millet as "poor people's food" has led to avoidance by upper and middle class consumers. In addition, governments often provide subsidies for wheat, rice, or maize-based foods that are denied to sorghum and millet processors. Industrialized countries export inexpensive wheat flour,

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maize meal, and rice to sorghum- and millet-producing countries, which means local sorghum and millet products cannot compete economically. Urban consumers want food products that deliver convenience, taste, texture, color, and shelf-stability at an economical cost, but sorghum and millet products usually cannot meet these requirements. Grain molds, weathering, and head bugs are major problems in many sorghum-producing areas.

In our experience, it is possible to produce outstanding products from sorghum and millet cultivars that have good processing quality. However, disaster strikes when products must be made with samples from the regular grain markets. It is not possible to compete with rice when 10% of the "white" sorghum kernels have a purple testa, resulting in a dark-colored product. This mixture of grains makes it difficult (if not impossible) to produce acceptable products. Locally grown maize also has problems, but in many countries the maize is grown by larger farmers and the quality is more uniform for processing. The lack of a consistent supply of good quality sorghum grain often precludes pilot plant production trials of new products.

The alleged poor nutritional quality of sorghum, especially due to tannins and poor protein digestibility, often is detrimental to its acceptance. Some key nutritionists and others believe that all sorghum contains tannins, thereby scaring away potential users. For example, a poultry nutritionist from India told me that he "would only feed sorghum if it was priced at 60 to 70% the value of maize." Upon further discussion, I learned he was afraid of the tannins in sorghum, even though most, if not all, Indian sorghum does not contain condensed tannins.

The "poor-feed" image of sorghum discourages food product development, even though good prototype products have been made by several multinational research and development centers. Usually such projects are killed by the marketing people who do not relish an up-hill battle to convince consumers to buy the product.

Environmental conditions during grain maturation greatly affect the appearance of the grain because the sorghum head is exposed to insects, molds, and moisture. The kernels are often attacked by grain-feeding bugs, and the damaged areas are ideal for attack by fungi. A hot and humid environment during and after maturation negatively affects grain quality. Molds discolor the grain, break down the endosperm, and significantly deteriorate processing qualities. Mold-damaged or weathered grain cannot be decorticated; the flour or grits are badly discolored and cannot be used for food. Moldy sorghums are impossible to malt for use in beer. The major fungi involved are *Fusarium*, *Alternaria,* and *Curvularia* species. Sorghum mold and weather damage are the most important limitations to sorghum improvement worldwide.

Strategies for Overcoming Constraints

The image of sorghum and millet as poor people's food must be overcome. We need to develop highly improved products from new sorghum that have attractive, more socially acceptable names. A new name, along with identity-preserved production schemes, would lead to improved acceptability. In our lab, we have used the term *JOWAR* to refer to special food sorghums to circumvent the undesirable image of sorghum or milo that exists in the U.S. The marketing of new grains calls for imagination along with new superior food types. This is a difficult task to accomplish, but if sorghum and millet are to be used in value-added products, it is necessary.

Development of Value-Added Products

The best strategy for developing convenient, shelf-stable sorghum and millet foods is to use identity-preserved grains to produce high-value products that can be priced slightly lower than imported products. The targets should be middle class and wealthy people where sufficient profits can be gleaned to allow for developing the industry. There is no need to develop low-cost, inferior quality foods. It is necessary to develop high value foods that appeal to the wealthy urban consumers who will pay for convenience, acceptable taste, and texture. An array of decorticated products, instant couscous, flours, grits, snacks, and others could be targeted. Rice is considered a convenience food in many areas because it is ready for cooking. Similar products, e.g., grits, flours, and meals, could be made from sorghum and millet.

Development of value-added products should follow this general procedure: 1) identify upscale products and niche markets (supermarkets); 2) develop sorghum and millet products using low-input technologies and identity-preserved grain (specify variety and hybrids); and 3) educate farmers and producers.

Identity-Preserved Production

The maize and soybean industries are rapidly expanding value-enhanced marketing of grains, where varieties or hybrids are grown specifically for enhanced nutritive or processing properties. The grain is identity-preserved and sold to the end user. High oil corn, waxy maize, white corn, and special soybean varieties for processing are some examples. These markets will continue to grow because they are cost-effective as long as all parties make a reasonable profit. Where will sorghum be? Unless significant effort is made to improve sorghum quality, the crop will continue to lose market share and will be less valuable than other grains.

We believe that sorghum and millet must be grown under identity-preserved systems if they are to be used for value-added food products. Such systems are difficult to promote in sorghum and millet producing areas because there must be control of seed quality, production, harvesting, storage, handling, processing, and marketing. An identity-preserved system can work best for relatively small-scale processors who have access to grain supplies and to local markets in which logistics and marketing are controllable. For example, modern large-scale milling systems for sorghum and millet installed in Nigeria and the Sudan failed due mainly to lack of a consistent quality grain supply and high costs of transporting finished products from the central milling location across the country. In contrast, the introduction of small mills in Botswana has been successful because they are adapted to local conditions.

Improvement of Grain Quality

Sorghum and millet breeding objectives should be aimed toward useful products per hectare, value-added characteristics, economic grain yields and quality, mold/head bugs/weathering resistance, and available screening methods. Plant breeders should consider yield in terms of useful quantities of food produced per unit of land. Breeding for yield without regard for quality is a mistake. Farmers in the semi-arid tropics have not planted improved sorghum varieties because they are susceptible to weathering and head bugs and have unacceptable processing and food properties. We reported years ago that a thin pericarp sorghum is unacceptable because the work required to dehull it by hand-pounding in a mortar and pestle is increased by 50% or greater. Therefore, sorghum breeders must recognize that food quality in many areas is critically important and is an essential part of grain yield. This has proven true in Honduras where Sureno, an improved sorghum, has been readily adopted by farmers because it has good tortilla-making qualities and a sweet juicy stalk that improves its forage quality.

In West Africa, a major priority should be to develop improved local varieties that are resistant to molds, weathering, and head bugs and have photosensitivity and good food quality (tan plant, straw color glumes). Such varieties could be utilized for identity-preserved sorghum production for value-added products. Until we obtain superior quality grains consistently (bright white or red color, no pigmented testa), sorghum and millet food use in urban areas is doomed. There are white and yellow seeded millets that have outstanding milling properties (hardness, spherical shape, white endosperm) and produce light color products. These might be preferred over purple or slate grey for use in specific value-added products.

Overcoming the Effects of Tannins in Sorghum

Sorghum and maize grains contain equal amounts of total phenols. Often laboratories apply general phenol assays to measure tannins, resulting in erroneously high values, even for sorghum that does not contain tannins. Tannin sorghum (brown sorghum) has a definitive pigmented testa caused by the combination of dominant B_1-B_2-S-genes. Such sorghum has significant levels of condensed tannins and some resistance to birds and grain molding. Sorghum tannins are catechins that cause reduced feed efficiency ranging from 10 to 30%, depending upon feeding systems, livestock species, and processing of the grain.

General phenol analysis methods often are used to determine tannins. All sorghum and other cereals contain many phenolic compounds that give a reaction for general phenols. Thus, Southeast Asian buyers often complain that U.S. sorghum contains high levels of tannins. In every instance, the analysis used is a general phenol assay which gives erroneous information.

The Vanillin-HCL method is the best test for tannin analysis in sorghum because it measures only condensed tannins, not total phenols. It uses catechin as a standard. Blanks should be subtracted from the readings since some indigenous compounds interfere with the assay. The catechin values arrived at by this method are only relative values since the standards are not sorghum tannins. Sometimes, tannic acid values are reported for sorghum, especially in the early literature. We now understand that sorghum does not contain any tannic acid. Thus, studies with tannic acid in animal feeding trials are irrelevant.

The effects of tannins can be overcome by adding formaldehyde in trace levels, malting, alkaline processing, and simply adding extra protein to the ration. Animals fed rations containing high-tannin sorghum will usually consume more of the ration to produce similar weight gain. However, the concern that animals will not consume brown sorghum is unfounded.

Feed Utilization of Sorghum and Millet

Sorghum is a good feed grain as long as it is supplemented properly for the particular species being fed. The nutritive value of sorghum for food and feed is misunderstood by potential users who think that all sorghum contains tannins and that high-tannin sorghum cannot be used as livestock feeds. Sorghum without a pigmented testa has 95% or greater the feeding value of yellow dent maize for all species of livestock. Pearl millet has outstanding feed value for poultry and swine because of its higher fat and improved amino acid content. The digestibility of sorghum is improved significantly by proper processing of the grain prior to feeding. Sorghum and millet are ground finely for use in swine and poultry rations, while a wide array of methods are used for ruminant feeds, including popping, steam flaking, rolling, reconstituting, and grinding. Steam flaking is a preferred way of processing grain for the feedlots.

Traditional Food Use of Sorghum and Millet

The proper sorghum and millet cultivars can be processed into a wide variety of acceptable commercial food products. These grains can be extruded to produce a great array of snacks, ready-to-eat breakfast foods, instant porridges, and other products. The flakes of a waxy sorghum obtained by dry heat processing can be used to produce granola products with excellent texture and taste. Tortillas and tortilla chips have been produced from pearl millet and sorghum alone or with maize blends. The sorghum products have a bland flavor while pearl millet products have a unique flavor and color. The critical limitation is the lack of cost-efficient, reliable supplies of grain.

Three classes of sorghum based on endosperm texture have been proposed: 1) hard — suitable for thick porridges and couscous, 2) intermediate — suitable for unfermented breads, boiled rice-like products, malting and brewing, and 3) soft — suitable for fermented breads. Thus, plant breeders selecting for food quality within a specific food category can visually select for certain kernel characteristics and texture. In general, within each hardness group, the preferred sorghum should have a white pericarp and tan plant color without a pigmented subcoat; however, there are exceptions. For example, the preferred pericarp color of sorghum for beer is red; a dominant intensifier gene gives a very bright, clear red kernel with an intermediate to soft texture without a pigmented testa.

Plant breeders can use grain hardness, density, and ease of pericarp removal for early generation selection for sorghum and millet quality. Then laboratory milling and cooking tests can be conducted in advanced generations followed by large-scale processing and cooking trials for advanced breeding materials. The assays that should be applied for each food category have been summarized by Rooney et al. (1986) and Murty and Kumar (1995).

Special processes are used to convert brown or high-tannin sorghum into foods. In some areas, brown sorghum is steeped in wood ashes, germinated, and used to produce thick porridges. Brown sorghum is preferred for traditional opaque beer production. 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. In some areas, brown sorghum products are preferred over white products. In East Africa, brown sorghum is added to opaque beer made from maize to improve the color and acceptability. In some areas, brown sorghum porridges are preferred. Malting and fermentation tend to improve the digestibility/nutritional value of brown sorghum.

Neither sorghum nor millet has gluten proteins. To produce yeast-leavened breads, sorghum or millet flour is usually substituted for part of the wheat flour in the formula. The level of substitution varies depending upon the quality of the wheat flour, the baking procedure, the quality of the sorghum or millet flour and the type of product desired. In biscuits, up to 100% of the flour can be sorghum or millet flour. The non-wheat flour tends to give a drier more sandy texture, so modifications to the formula must be made. The use of sorghum and millet in composite flours depends upon the cost and availability of acceptable quality flour. Sorghum has a definite advantage over maize in composite flours because of its bland flavor and white color. Unfortunately, high quality sorghum flour is usually unavailable because acceptable quality grain is lacking.

Dry Milling Quality

The milling quality of sorghum and millet is determined mainly by kernel size, shape, density, hardness, structure, presence of a pigmented testa, pericarp thickness, and color. Kernels with outstanding dehulling properties have a high proportion of hard endosperm, a thick white pericarp, and no pigmented testa. Soft floury kernels disintegrate during dehulling and cannot be milled efficiently. For hand dehulling, a thick starchy mesocarp (zz) reduces labor 50% or more. Long, slender pearl millet kernels have very poor dehulling properties, while white kernels have the highest yields of the preferred light color flour.

In general, abrasive milling techniques are effective. The barley pearler, Kett Mill, TADD, and Satake Rice Pearler have been used to determine milling properties of sorghum and millet (Reichert et al., 1988; Munck, 1995) in the breeding program. In effect, these techniques are similar with varying degrees of force applied to the grain to abrasively remove the pericarp. Good milling cultivars retain their integrity and allow the pericarp to be removed to produce high yields of white decorticated kernels. Hardness and density are strongly positively related to good milling properties. Adequate techniques to select for food quality are currently available for use in breeding programs.

Improving Sorghum Digestibility

In our research program, we have tried for thirty years to improve the digestibility of sorghum through breeding. Invariably, types that have high digestibility according to *in vitro* tests also have soft, floury endosperm characteristics. Attempts to develop white or red sorghum with high digestibility have resulted in hybrids with poor yields and greater susceptibility to attack by molds and weathering. It is difficult to improve digestibility without enhancing the susceptibility of the grain to deterioration, because sorghum kernels are exposed to ambient conditions during maturation and are prone to attack by molds and insects.

Digestibility for ruminants and possibly swine is improved with waxy sorghum, but that improvement is accompanied by poor seed emergence and viability. Current waxy sorghum hybrids have lower yields of grain, although yields could be improved by greater breeding and selection efforts. A heterowaxy hybrid, where one parent is waxy and one nonwaxy, may provide a high-yielding sorghum with some improvement in digestibility. Some of the yellow endosperm hybrids thought to be more digestible have seed vigor and emergence problems. Therefore, we must be careful in the quest to develop highly digestible sorghums. The most efficient way may be to develop improved, more efficient processing techniques for sorghum grains bred to resist the molds and post-harvest weathering that occurs during sorghum production in most areas.

Reducing Effects of Molds, Insects, and Weathering on Grain Quality

Problems with grain molds, weathering, and head bugs in many sorghum producing areas can be overcome most quickly by the production of white, tan plant sorghum with straw-colored glumes. This is critically important in West Africa, where the new improved types have been significantly devastated by head bugs and mold. For example, N'Tenimissa has been recently released in Mali as the first tan plant local sorghum. It has some agronomic problems, but it definitely has improved grain characteristics for processing into food products. In the meantime, it is hoped that head bug and mold resistance can be obtained in adapted sorghum with higher yields.

Sorghum with open panicles, thin pericarp, condensed tannins, corneous endosperm, and large, tight glumes is generally considered more resistant to molds and weathering (Waniska et al., 1992). Antimicrobial proteins found in sorghum may lead to the production of white sorghum with more tolerance to molds. Weathering and molding of pearl millet does occur, but it is not usually a significant problem.

Sorghum does not develop aflatoxins prior to harvest like maize does. Sorghum contains A. flavus and other species, but, apparently the exposure of the grain to the atmosphere prevents significant levels of aflatoxin formation. Sorghum containing aflatoxin was present in 1996 in some areas of South Texas; however, the aflatoxin developed after harvest during storage of high moisture grains. In addition, sorghum does not produce significant amounts of fumonisin. This must be confirmed, but the relative resistance of sorghum to field contamination by these mycotoxins is a major advantage for sorghum over maize. As maize is grown under more marginal conditions, the risk of increased levels of mycotoxins must be considered.

Future of Sorghum and Millet

It is possible for consumption of sorghum and pearl millet to increase, as is the case in Nigeria where a change in government policy has greatly expanded the use of sorghum for brewing and in a wide array of malt beverages, malt extracts, biscuits, and other confectionary products. The use of sorghum would not have occurred without the change in government policy. Still, acquiring sufficient quantities of sorghum of good quality for processing is a major problem in Nigeria. In some cases maize is used instead of sorghum because more uniform supplies of consistent quality are available. Industry is slowly increasing special sorghum varieties with improved malting properties. Developing identity-preserved grains is important if sorghum and millet are to be accepted in urban foods.

Greater utilization of sorghum and pearl millet can occur through use of improved varieties, improved technologies, and government policy changes that promote indigenous cereals. The economics that are true today may quickly become obsolete when one of the above components changes. In 1996, the price of wheat increased rapidly, and interest in potential use of sorghum flours rose significantly. This interest has decreased rapidly, however, as the price of wheat flour has decreased. Thus, the major goal of sorghum and pearl millet research activities should be to develop the best quality, highest yielding cultivars possible to take advantage of whatever markets are economically viable. For example, sorghum in composite flour for bread is significantly better than maize flour, but unfortunately insufficient sorghum flour is available, so maize is often used. The bland flavor and white color of sorghum flour is a distinct advantage of sorghum over maize. Yet today in Mali, yellow corn flour is proposed for incorporation into composite breads. It is critically important that research continue to develop superior sorghum and pearl millet cultivars which will provide the grain required when new processes or old technologies become economically important. Sorghum and millet utilization as food will continue to decrease in urban areas until new convenient shelf-stable products are developed.

Sorghum and millet play important roles where maize production is marginal or likely to be contaminated with aflatoxin and fumonisins. The challenge to improve sorghum and millet utilization is great. Progress can be made but we must carefully evaluate our strategy. Clearly improved quality for food, feed, and industrial use must be a part of it.

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