

TRADITIONAL GRAINS FOR LOW ENVIRONMENTAL IMPACT AND PROCESSING INTO PROFITABLE HEALTH FOODS

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INTRODUCTION

Sorghum and millets, the indigenous grains of Africa, provide sustained production under harsh conditions that often cause crop failure for maize. In addition, these grains often have significant health benefits that are just now being widely recognized. Maize is a magnificent crop when water is available, but it often fails when water is limiting. In addition, the maize grain produced is frequently contaminated with aflatoxins that are highly toxic to humans and animals. In comparison, sorghum and millets are relatively free of aflatoxins when they are harvested.

Progress is being made to profitably market traditional grains by producing good quality local foods. Farmers are learning how to supply good quality grain to processors who learn to pay a premium price. Thus, profits are being made along the supply chain. Because profits are realized, the participants can afford to use new technologies, varieties with better quality, fertilizer, and improved threshing / cleaning methods. Special sorghum and millet varieties have high levels of antioxidants and other bioactive compounds that are linked to anticancer and cholesterol-reducing activities. These grains are more slowly digested which helps control type 2 diabetes. They contain a wide variety of phenols and other healthy compounds.

The purpose of this manuscript is to discuss the potential of sorghum and millets to produce sustainable value-added profitable and healthful foods for urban and village markets. There is a critical need for value added supply chain management systems to provide consistent supplies of grain for processing at profitable prices. We need young scientists who work in integrated systems involved in promoting the production and profitable marketing of food and feeds from local crops, especially sorghum and millets that are uniquely adapted to African conditions.

ADVANTAGES OF SORGHUM AND MILLETS

These grains produce grain and forage under high levels of drought stress. Their water use efficiency has been well documented. In addition, the grains produced are nutritious and can be processed into excellent food products. Unfortunately, they are not always available in sufficient quality and quantities for processing. They have a major health advantage over maize because they produce significantly less aflatoxins in the field. This information has not been documented properly, but it is clear that sorghum and millets have low levels, if any, when they are harvested. In contrast, maize often has dangerous levels of aflatoxins present in the field especially when it is grown in hotter, drier areas. In Texas, maize is frequently contaminated with aflatoxin content above 20 ppb at harvest, while sorghum is not. In addition, sorghum does not produce significant amounts of fumonisin. The relative resistance to field contamination of sorghum 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 should be considered. Millets have not been implicated in any

problems with aflatoxins either.

URBAN CONSUMER DEMANDS

Urban consumers want food products that deliver convenience, taste, texture, color, shelf-stability and nutrition at an economical cost. Upscale sorghum and millet products that meet these requirements are becoming available in some urban areas. Major constraints are listed in Table 1. In our experience, companies can and are producing outstanding products from sorghum and millet cultivars when they have good quality grain for processing. However, disaster strikes when products must be made with grains purchased from regular grain markets. Government policies significantly affect the utilization of local cereals because subsidized wheat flour and other products are often lower priced than local grains. These policies are changing rapidly now with increased demand for grain-based alcohol for fuel. There simply will not be enough grains to meet all the current needs; hence, surplus production may cease.

Table 1. Major Constraints to Sorghum and Millet Utilization

- Lack of consistent, uniform quality grain supplies
- Logistics/markets
- Subsidized imported cereals
- Extension of existing processing technology unavailable
- Few shelf-stable convenience foods
- Governmental policies
- Subsidized maize, rice or wheat-based food systems
- Poor image of sorghum and millets
- Nutritional myths

The high cost and often very poor quality, i.e., 15-30% sand and impurities, of local grains make it difficult to market acceptable food products. However, more local grain products are being sold. Demand is increasing for both domestic and export markets. This is especially true in Dakar Senegal where a wide variety of high quality pearl millet products are marketed profitably with increasing demand. These processors have a strategy to produce high quality products (Table 2). They cannot meet the local or export demands presently.

Table 2. Strategy for Sorghum and Millet Value-Added Products

- Identify upscale products
- Niche markets – supermarkets, small shops,
- Develop sorghum and millet traditional products
- Use appropriate technologies
- Produce consistent products with good quality
- Specify variety and hybrids
- Educate farmers and producers
- Economics - share the profits of value-added processing

The major limitation is the lack of high quality millet and sorghum grain in sufficient quantities for processing. More efficient methods of threshing and cleaning the grain to remove sand and other impurities are essential. A clean grain supply is critically important. Lack of this has caused many processors to fail.

Another important factor to promote sorghum and millet value is the significantly improved processing quality that is found in some varieties and improved cultivars. N'Tenemissa, a photosensitive variety that avoids head bugs and molds in Southern Mali, has demonstrated excellent processing properties and has been identity preserved, stored, handled and processed into flour for local food products in Mali. Thlack, a millet variety in Senegal, has given excellent composite bread with increased loaf volume.

Simple methods to assess quality are required to facilitate supply chain management. A set of simple standards along with practical specifications for each important quality criteria is required. These specifications must be simple, practical and agreeable to both producers and processors. The type, or cultivar, of grain can be determined by mutual agreement, but environment will modify grain quality which must be measurable. Communications among seed producers, production specialists, farmers and processors is required. Contracts are required along with credit systems to build grain storage facilities to hold grain throughout the year and assure a consistent supply of grain for the processor. Mutual understanding and good will are needed for this to work.

In South Africa, in spite of a 14% Value Added Tax on processed sorghum products, significant amounts of decorticated sorghum products are sold to consumers. The product made from local sorghums with red or brown color is consumed even though it is higher cost than maize meal. The major problems always relate to the lack of a good quality supply of grain for processing at affordable prices. Some processors have solved these problems by investing in cleaning facilities and by selling only high quality products. This improves the image of local grains and gives the convenience desired by modern consumers. Such products are successful in competing with maize and rice since they have the convenience and quality desired by consumers.

A consistent supply of good quality grain at a price that allows the processor to make sufficient profit to share with all participants in the value added supply chain (Table 3) must be the goal. Profit for all is necessary to make the scheme work. It requires identification of quality by using simple objective procedures agreed upon by all parties.

Communications are critically important. Initially, it is inherently difficult for producers and processors to understand each other's needs and problems.

Table 3: Components of the Value Added Supply Chain

Seed supplier (seed production) – quality and purity
Grain producer
Harvesting
Storage
Handling and transportation
Processing into products
Marketing

Over time, each understands the others problems and limitations, and the system will work provided profits are shared by all. These systems are being developed in many countries on small to large scale basis. Large breweries are contracting for production of grains for malting/brewing.

The image of sorghum and millets as a poor man's food can be overcome by producing high quality products that appeal to urban customers and export markets alike. 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 are middle class or wealthy people where prices provide profits for all. There is no need to develop low cost, inferior quality foods that do not provide any profits.

FUNCTIONALITY OF SORGHUM AND MILLETS

There are many different sorghums that are used in various ways. Functional advantages for sorghum include a white, light color and bland flavor with excellent processing properties similar to rice for use in snacks, breakfast cereals and an array of flours, grits, meals and porridges. Special sorghums have a large variety of different kinds of phenols and other bioactive components that have nutraceutical benefits. They have reduced/slower digestibility because some of the components thought to be condensed tannins complex with proteins and carbohydrates. It does not contain gluten, and its slower hydrolysis makes it attractive to diabetics, celiacs and for ethnic markets. However, the bland flavor and light color of food type sorghums afford a real advantage in functionality to sorghum.

Pearl millet has a strong flavor and dark color that is desired in millet consuming areas. For example, in Senegal couscous, flours, grits, snacks are sold domestically and for export. Yogurt containing 30% pearl millet is quite popular. In fact, they cannot supply the demand for these products. Some white and yellow grain types have functional advantages for processed foods. Precooked fonio couscous has been profitably sold for many years in West Africa, especially Mali. Consumers like the convenience and appreciate the lack of sand in the product. An array of attractive decorticated products is available.

Many food scientists do not understand the need for supply chain systems. New, improved equipment and processes are not always the answer. Modern machinery works effectively on clean grain, but is easily damaged by debris in grain. Unfortunately, this happens all too frequently. Thus, the need for the supply chain system with scientists understanding and working as part of the whole system is required for long-term progress.

Technology for processing sorghum and millets is available, and is not the most limiting factor. In most cases, existing milling techniques applied to good quality grain can make acceptable products. More efficient technology is always welcome, but we cannot wait until we have perfect processing procedures. The perfect new process will not work efficiently on poor quality grain.

PLANT BREEDING AND IMPROVEMENT OF GRAIN QUALITY

Plant breeders should consider yield in terms of useful quantities of food produced per unit of land, whether it is processed cereals, or meat and eggs (Table 4). Poultry production is expanding rapidly in many areas and makes use of off-quality grains that cannot be processed into foods. Feed use is a critical part of the cereal utilization system. Breeding for yield without regard for quality is a mistake. Farmers in the Semi-Arid Tropics have not planted many improved sorghum varieties in part because they are susceptible to weathering and head bugs, and have unacceptable processing and food properties. For example, women will not accept a thin pericarp sorghum because the work

required to dehull it by hand pounding in a mortar and pestle is increased by 50% or greater. Therefore, it is important that sorghum breeders recognize that food quality is critically important and is an essential part of grain yield. This has proven true in Central America where new improved sorghum varieties have been readily adopted by farmers because they have good tortilla-making qualities and sweet juicy stalks that improve forage quality. They are used by small bakeries to substitute for part of the wheat flour in baked products. The operations acquire grain from local farms.

Table 4. Properties of New Varieties / Hybrids

Optimum grain yields and quality
Photosensitivity required in some areas
Avoids - molds / weathering / head bugs
Tan plant, straw glumes
Bright white or red color
Improved milling yields - hardness, spherical shape, white endosperm
White / yellow millets - light color products for processing
Special types for health foods, i.e., tannin sorghums

In the more humid areas of West Africa, a major priority is to develop improved local varieties that have photosensitivity and good food quality (tan plant, straw color glumes). Such varieties can be utilized for identity preserved sorghum production for value-added products. Until we obtain superior quality sorghums consistently, sorghum food use in urban areas is difficult. An attractive alternative is to market tannin sorghums in special, healthy foods, i.e., antioxidants, slowly hydrolyzed.

SORGHUM IMAGE IMPROVING

The allegedly "poor nutritional quality" of sorghum is detrimental to its use in foods and feed. Tannins and poor protein digestibility are major problems in the eyes of some. Often, key nutritionists and others believe that all sorghums contain tannins, and thereby potential users are scared away. For example, a poultry nutritionist from India indicated he "would only feed sorghum if it was priced at 60 to 70% the value of maize" because of the tannins in sorghum, even though Indian sorghums do not contain condensed tannins.

Progress has been made in recent years in the United States to provide identity preserved white food sorghums for use in domestic, ethnic, and dietary foods. These sorghums have excellent properties and are appreciated by consumers; they are exported to Japan for snacks and other processed products. The identity preserved food sorghums have stimulated significant interest and demand for food products from sorghum. Reasonable chances for growth of these markets exist, provided progress to produce good quality sorghum continues. Unfortunately, white food sorghums cannot be grown in many environments because they become unacceptably discolored. Under some environments, sorghums with condensed tannins and other pigments must be grown to avoid production problems. Certain varieties are grown in areas because, over the years, they fit the environment. Such is the case for sorghums that contain condensed tannins. They are usually grown in more humid areas because they have tolerance to birds, molds and discoloration.

TANNINS IN SORGHUM - GOOD AND BAD

Many scientists and others believe that all sorghums contain tannins. The sorghums without a pigmented testa do not contain tannins; they should be referred to as “tannin free”. Often laboratories use general phenol assays to measure tannins which result in erroneous information since all sorghums contain phenols; but, most do not contain tannins. The tannin sorghums (also misleadingly called brown sorghums) have a very definitive pigmented testa which is caused by the combination of dominant B₁-B₂-S-genes. Such sorghums have significant levels of condensed tannins with resistance to birds and grain molding.

Sorghum tannins are polymers of catechins that cause reduced feed efficiency ranging from 5% or more depending upon feeding systems, livestock species, and processing of the grain. While the tannins are undesirable for livestock feeding, they may be highly desirable for human health because they slow digestibility, have high antioxidant levels, and appear effective against some cancers, especially colon cancer. The slower digestibility has applications in type 2 diabetes. Whole grain high tannin sorghum and tannin bran fractions are important sorghum products with health benefits.

The tannin sorghums have high antioxidant activities and may be a very important source of nutraceuticals. Thus, we might someday use sorghums with a pigmented testa and dominant spreader genes as potent sources of antioxidants that provide more efficient sources than fruits or berries. Other sorghum genotypes have a host of different phenolic compounds with potential health applications.

DRY MILLING QUALITY

The milling quality of sorghum and millets is determined mainly by kernel shape, density, hardness, structure, presence of a pigmented testa, pericarp thickness and color. Kernels with a high proportion of hard endosperm, white, thick pericarp without a pigmented testa have outstanding dehulling properties. 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 spherical kernels have the highest yields of decorticated grain. The white tan food sorghums have significantly improved yields of light-colored flour and decorticated kernels. The problem is that they cannot be consistently produced when they mature under humid conditions because of molds and related problems.

FOOD UTILIZATION

Sorghum and millets can be processed into a wide variety of very 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. Sorghum flakes obtained by dry heat processing can be used to produce granola products with excellent texture, taste and high antioxidant levels. Tortillas and tortilla chips have been produced from sorghum and pearl millet alone or with maize blends. The sorghum products have a bland flavor, while pearl millet products have a unique strong flavor and color. The critical limitation is cost efficient, reliable supplies of grain.

Neither sorghum or millet have gluten proteins, so to produce yeast-leavened breads, they are 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, (cookies) up to 100% sorghum or millet

flour can be used. The non-wheat flour gives a drier, sandier texture, so the formula must be modified. White sorghum has a definite advantage over maize and millet in composite flours because of its bland flavor and light color. The blending of sorghum flour with wheat flour for baked products is likely to expand because of extremely high wheat prices. The dark color of tannin sorghums give whole grain products an attractive brown color.

FEED UTILIZATION OF SORGHUM AND MILLETS

Sorghum is a very good feed grain as long as it is properly supplemented for the particular species desired. Sorghums without a pigmented testa have 95% or greater the feeding value of yellow dent maize for all species of livestock. Pearl millet has outstanding feeding value for poultry and swine because of higher fat content and increased essential amino acid content.

Feed and food use of sorghum and millets go together since not all grains will have desirable food processing properties; therefore, poor quality grain will need to go into feeds. Failure to meet food specifications will lead to its use in feeds. Feeders also require a constant supply of grain at affordable prices relative to the price of their products, i.e., poultry. Sorghums that fail to meet food requirements will be used for feeds. Thus, food and feed uses are each necessary for sorghum and millet success in food products.

Tannins in sorghum are not toxic, but do reduce feed efficiency. Animals fed rations containing high-tannin sorghums usually consume more of the ration to produce similar weight gains which reduces the feed efficiency significantly. The concern that animals will not consume tannin sorghums is erroneous.

EFFECT OF MOLDS, INSECTS AND WEATHERING ON GRAIN QUALITY

Grain molds, weathering and head bugs are major problems in many sorghum-producing areas. 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.

The molding problem can be overcome most quickly by producing white, tan plant, photosensitive sorghums. This is critically important in West Africa where the new improved types have been significantly devastated by head bugs and mold. For example, variety N'Tenimissa has been recently released in Mali as the first tan plant improved local photosensitive sorghum. It definitely has improved grain characteristics for processing into colorless products. The white sorghums have been successfully used in a wide variety of food products, ranging from biscuits to decorticated rice-like convenience foods. Farmers like them for their own food use. However, their yields are lower than some earlier sorghums. Thus, for feed use the higher yielding types that discolor are more efficient while the lower yielding types could be used for food.

The identity preserved production has resulted in improved profits for all parts of the value chain. Here again we see the need to consider all aspects of the supply chain system. Soft sorghums cannot be grown when the grain matures under hot humid conditions. However, soft grains can be grown in areas where they mature under hot, dry conditions such as the sorghums in many areas of the Sudan and Ethiopia. Scientists must recognize the environmental conditions in which the grain is produced to obtain grains for processing. The reduced levels of aflatoxins and drought tolerance of sorghum

and millets give them unique adaptation to many African conditions.

Acknowledgement: I thank all of my INTSORMIL colleagues, national scientists and graduate students who I have had the good fortune to cooperate with over the past 28 years. They have contributed much to our understanding of factors that affect the utilization of local grains, and how to safely increase their utilization in foods and feeds by improving quality through supply systems. The work has only started and must be continued by dedicated, intelligent young scientists who hopefully will not repeat the mistakes that we have made.