OVERVIEW: SORGHUM AND MILLET FOOD RESEARCH FAILURES AND SUCCESSES

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Sorghum and millets can have excellent quality for processing but to obtain that inherent quality a value added, chain securing, identity preserved grain for processing into profitable upscale urban products is necessary. Processing technology is not the major obstacle to successful production of products. Consistent supply of a modest quality grain is the major constraint. Several examples of failures and recent successes will be discussed.

Several myths affect the perceived nutritional and processing quality of sorghum. Many sorghums are tannin free, have about the same levels of phytin and phytic acid as maize and other cereals and the digestibility is only slightly reduced compared to maize. It is true that sorghum proteins are slightly less digestible than maize but as eaten in processed forms they are readily available and do not cause major problems. The nutritional value of even the high tannin grains is acceptable when fed to livestock since they consume more sorghum to produce about the same amount of gain. Thus, the feed efficiency is reduced but contrary to popular belief the animal do not get sick and do not die. These myths are largely extended by scientists who read review articles where old data are taken out of context by reviewers and they have a significant impact on utilization of sorghum.

The major constraint to production of consistently high quality grain is the destruction or severe damage caused by insects and molds. The discoloration and softening of the grain reduces processing quality significantly. Efforts to breed mold resistant sorghums have been relatively unsuccessful. Improved resistance to molds in white or red sorghums is needed. Also, the development of sorghums with improved digestibility may exacerbate the damage caused by molds. Thus, highly digestible types may be limited to production in extremely dry environments where grain deterioration does not occur, i.e. Sudan and Ethiopia. It is doubtful that they will ever be useful in the sorghum belt in the USA and other areas where molds occur regularly.

Development of higher lysine and tryptophan sorghum cultivars would be extremely beneficial since quality protein maize production is expanding. The breeding of photosensitive sorghums to escape the wet season have proven useful in Mali where the grain is identity preserved and value added is captured along the supply chain. Where possible white, tan plant straw color glumes and grain with a spherical medium to hard endosperm is require. The grain yields must be equal to or better than the varieties or hybrids being replaced.

INTRODUCTION

Many foods have been produced from sorghum and millets but they often fail for various reasons. I will summarize some of my experiences with sorghum and millet products and present some future research needs to improve their use.

CONSUMER DEMANDS

Urban consumers want food products that deliver convenience, taste, texture, color and shelf-stability at an economical cost. Upscale sorghum and millet products that meet these requirements are usually not available in urban areas. We have made excellent prototype products from sorghum and millet using grain with good processing quality. However, disaster strikes when products are made with grains from the regular markets. The poor quality grain cannot be made into acceptable value-added products. It is impossible to compete with rice when 10% of the "white" sorghum kernels have a purple testa which gives a dark-colored product.

Other major constraints (Table I) are discussed. Government policies significantly affect the utilization of local cereals because subsidized wheat flour and other products are often lower priced than local grains. The high cost and poor quality of local grains make it difficult to market acceptable food products.

TABLE I 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 - VAT on sorghum-RSA
Subsidized Maize, rice or wheat-based food systems
Poor image of sorghum and millet
Nutritional myths - tannins, poor digestibility
Grain molds

More local grain products are being sold and demand is increasing for both export and domestic markets. This is especially true in Dakar, Senegal where a wide variety of high quality pearl millet products are marketed profitably. These processors have learned to produce high-quality products that are in demand by local consumers. They are so successful that they cannot meet local or export demand presently.

In South Africa, in spite of a local 14% value-added tax on processed sorghum products, significant amounts of decorticated sorghum are sold to consumers. The product made from local sorghums with red or brown color is consumed even though it costs more than mealy meal. Thus, there is a demand for sorghum products perhaps more than we realize. The major problems always relate to the lack of a good-quality supply of grain for processing. 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 rice and wheat since they have the convenience and quality desired by consumers.

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 and for export to Japan for snacks and other products. Many new ethnic and special dietary recipes have been developed and published in cookbooks. The white food sorghums have excellent properties and are appreciated by consumers. 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.

VALUE-ADDED SUPPLY CHAIN

Excellent food products can be and are made from sorghum and millets; however, the lack of a consistent supply of good quality grain for processing usually precludes successful marketing of these products. The value-added supply chain includes:

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

The major limitation is the lack of high quality grain in sufficient quantities for processing. More efficient methods of threshing and cleaning the grain to remove sand and other impurities are essential. Millets and sorghum grains in existing markets are extremely variable in kernel size, color, and cleanliness. In the fact-finding trip, the processors in Senegal indicated clearly that they want cleaner and less variable grain. In addition, some varieties and improved cultivars are available that will lead to significantly improved processing quality. N'Tenemissa, a photosensitive variety that avoids head bug and molds, has demonstrated excellent processing properties and has been identity preserved, stored, handled and processed into flour for composite flours, decorticated rice-like products, and sold as clean food types of sorghum on a limited basis in Mali. Thlack, a millet variety in Senegal, has given excellent composite bread with increased loaf volume.

Methods to assess quality are required to facilitate supply chain management. A set of standards along with practical specifications for each important quality criteria is required. These specifications must be agreeable and practical both to producers and processors. The type, or cultivar, of grain can be determined by mutual agreement, but environment will modify grain quality and this 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 to assure a consistent supply of grain for the processor.

Profit for all is necessary to make the scheme work. Communications are critically important. It is inherently difficult for producers and processors to

understand each others needs and problems. A long-term relationship between producers and processors is required.

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In addition, some varieties and improved cultivars are available that will lead to significantly improved processing quality. N'Tenemissa, a photosensitive variety that avoids head bug and molds, has demonstrated excellent processing properties and has been identity preserved, stored, handled and processed into flour for composite flours, decorticated rice-like products, and sold as clean food types of sorghum on a limited basis in Mali. Thlack, a millet variety in Senegal, has given excellent composite bread with increased loaf volume. A supply chain management scheme would allow for introduction of new cultivars with better quality.

STRATEGY FOR VALUE-ADDED PRODUCTS

The best strategy for developing convenient, shelf-stable SM foods is to use identity preserved grains to produce high-value products that can be priced slightly lower than imported products (Table II). The targets should be middle class and wealthy people where sufficient prices can be obtained to provide profits for all. There is no need to develop low cost, inferior quality foods that do not provide significant profits.

The image of Sorghum and millet as a poor man's food can be overcome by developing highly improved products that have attractive, more socially acceptable names that appeal to wealthy consumers. The new name along with identity preserved production schemes would lead to improved acceptability. The marketing of new grains calls for imagination along with new superior types.

TABLE II Strategy for Value-Added Products

Identify upscale products
Niche markets - supermarkets
Develop Sorghum and millet products
Use low input, appropriate technologies
Use identity preserved grain
Specify variety and hybrids
Educate farmers and producers
Economics - share value-added processing profits with members of the supply chain.

FUNCTIONALITY OF SORGHUM AND MILLETS

Functional advantages for sorghum include a white, light color and bland flavor without danger of non-GMO that has excellent processing properties similar to rice for use in snacks, breakfast cereals and an array of flours, grits, meals and porridges. There are many different sorghums that are used in various ways. However, the bland flavor and light color of food type sorghums afford a real advantage in functionality to sorghum. It does not contain gluten and its slower hydrolysis makes it attractive to diabetics, celiacs and ethnic groups. In addition it is an alternative to rice in extruded and processed foods because of its bland flavor, light color and good expansion.

Pearl millet has a stronger flavor and dark color that is desired in millet consuming areas. For example in Senegal many processed products are sold domestically and for export. A yogurt containing cooked pearl millet grits is profitable. In fact they cannot supply the demand for these products. Some white and yellow grain types would have functional advantages for processed foods. A company in Senegal is profitably selling a pearl millet-based extruded snack.

Rice is considered a convenience food in many areas because it is ready for cooking. Similar products, e.g., meals, couscous, flours, grits, snacks made from sorghum and millet could be targeted. There are numerous examples of small entrepreneurs in Bamako, Mali profitably selling locally milled corn products because they produce a high quality meal that can be cooked conveniently. These ladies provide a convenience ready to eat product that consumers desire by maintaining good consistent quality.

Technology for processing SM 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

For plant breeders, yield should be considered in terms of useful quantities of food produced per unit of land (Table III).

TABLE III SM Breeding Objectives

Useful products per hectare
Value-added characteristics
Need economic grain yields and quality
Mold/head bugs /weathering resistance
Screening methods available

Breeding for yield without regard for quality is a major mistake. Farmers in the Semi-Arid Tropics have not planted many improved sorghum varieties because they are susceptible to weathering and head bugs, and have unacceptable processing and food properties. For example, we showed many years ago that women will not accept a thin pericarp sorghum because the work required to dehull it by hand pounding is increased by 50% or greater. Therefore, it is important that sorghum breeders recognize that food quality in many areas is critically important and is an essential part of grain yield (Table IV). This has proven true in Honduras where Sureno, an improved sorghum has been adopted by farmers because it has good tortilla-making qualities and a sweet juicy stalk that improves its forage quality.

TABLE IV 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, no pigmented testa
Milling yields - hardness, spherical shape, white
White/yellow millets - light color products for processing

In the more humid areas of West Africa, a major priority should be to develop improved local varieties that 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 sorghums consistently, sorghum food use in urban areas is doomed.

SORGHUM IMAGE

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 most, if not all, Indian sorghums do not contain condensed tannins.

Tannins in Sorghum

Many scientists and others believe that all sorghums contain tannins. The sorghums without a pigmented testa do not contain tannins and so they should be referred to as "tannin free". Often laboratories use general phenol assays to measure tannins, which results in erroneous information since all sorghums contain phenols but most do not contain tannins. The tannin sorghums (brown sorghums) have a very

definitive pigmented testa which is caused by combination of dominant B_1-B_2-S-genes. Such sorghums have significant levels of condensed tannins with resistance to birds and grain molding.

The tannin sorghums decrease feed efficiency by about 10% when fed to livestock. But they do not cause any other problems. Sorghum tannins are catechins which cause reduced feed efficiency ranging from 5 to 30%, depending upon feeding systems, livestock species, and processing of the grain.

The tannin sorghums have high antioxidant activities and may be a very important source of nutraceuticals. Thus we might someday use the sorghums with a pigmented testa and dominant spreader genes as potent sources of antioxidants that provide more efficient sources than fruits or berries.

DRY MILLING QUALITY

The milling quality of sorghum and millet is determined mainly by kernel shape, density, hardness, structure, and 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.

FOOD UTILIZATION

The proper SM cultivars 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. 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 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 again 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 more sandy 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.

FEED UTILIZATION OF SM

Sorghum is a very good feed grain as long as it is properly supplemented for the particular species fed. 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 feed value for poultry and swine because of higher fat content and increased essential amino acid content. Feed and food use of sorghum and millet go together since not all grains will have desirable food processing properties so the poor quality grain will go into feeds.

Methods to eliminate the tannins have been devised. Effects of tannins are overcome by addition of formaldehyde in trace levels, malting, alkaline processing, and adding extra protein to the ration. 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.

IMPROVING SORGHUM DIGESTIBILITY

It is difficult to improve digestibility without enhancing the susceptibility of the grain to deterioration since sorghum kernels are exposed to ambient conditions during maturation, and are prone to attack by molds and insects.

Soft, digestible sorghums are destroyed by molds in the field prior to harvest except in very dry areas i.e., Sudan, Ethiopia. Thus, efforts to enhance digestibility of sorghum must be done with care.

Waxy sorghums have improved digestibility for ruminants and possibly swine, but, that improvement is accompanied by poor seed emergence and viability. Current waxy sorghum hybrids have lower yields of grain, although that can be improved by greater breeding and selection efforts. A heterowaxy hybrid, where one parent is waxy and one nonwaxy, provides high-yielding hybrids with some improvement in digestibility.

Some yellow endosperm hybrids that are more digestible have reduced seed vigor and poor emergence. Thus, the most efficient way to increase sorghum digestibility is to properly process it. Thus, the emphasis should be to breed grains that resist molds and post harvest weathering. It is not feasible to grow soft, floury sorghums in most areas of production. The Sudan and some other areas of the world where extremely dry conditions occur after anthesis are exceptions to this statement.

Increasing the levels of lysine and tryptophan in sorghum is extremely valuable n terms of human and animal nutrition. Developing high yielding sorghums with improved levels of lysine and trypotophan would greatly enhance its value for both humans and animals.

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. This problem can be overcome most quickly by the production of white, tan plant, straw-colored glume photosensitive sorghums. This is critically important in West Africa where most new improved types have been devastated by head bugs and mold. For example, N'Tenimissa recently released in Mali as the first tan plant local photosensitive sorghum. It has improved characteristics for processing into a wide variety of food products ranging from biscuits to decorticated rice like convenience foods. The principle has been demonstrated; more extensive production is being encouraged.

Mycotoxins

Sorghum does not develop aflatoxins prior to harvest like maize does. Sorghum contains *Aspergillus flavus* and other species, but, apparently the exposure of the grain to the atmosphere prevents significant levels of aflatoxin formation in the field. Sorghum containing aflatoxin occurs during improper storage of high moisture grains. In addition, sorghum does not produce significant amounts of fumonisin. The relative resistance to field contamination of sorghum by these major 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. Sorghum has less problems with mycotoxins. There is less information on pearl millet but it evidently does not produce significant levels of aflatoxins and fumonisins in the field either.

ACKNOWLEDGEMENTS

I thank all the national INTSORMIL colleagues and scientists, graduate students that I have cooperated with over the past 22 years. They have contributed much to our improved understanding of factors that affect the utilization of local sorghum and millets and how to define quality in breeding and improvement programs.