\12✓ CP 680

Laboratory Procedures for Evaluating Grain and Food Quality of Sorghum and Pearl Millet: Problems and Prospects

V. Subramanian and R. Jambunathan[1]

Abstract

To understand the processing and food quality characteristics of sorghum and pearl millet and to improve their utilization, standard laboratory tests are essential, and they are useful in screening breeders' samples. Discussed herein are methods currently available for evaluating various grain characteristics that influence food quality. Problems faced in laboratory evaluation procedures are also discussed, as are areas for further research. A comparison of the laboratory method of dehulling with batch dehulling may lead to the identification of a suitable screening method. There is a need to conduct village-level surveys in African countries to better understand the utilization of sorghum and pearl millet. It is important to conduct taste evaluations in regions where these grains are consumed. Suggestions for increased utilization, including possible alternative uses, are included.

Introduction

Sorghum and pearl millet will continue to be used for traditional foods in the semi-arid tropics of Africa and Asia, although maize and wheat may replace them partially. Local cultivars are usually preferred over high-yielding varieties and hybrids. The preference for local cultivars is due to their good processing characteristics, acceptable quality, and storability as prepared food. Several grain factors are genetically controlled and the breeder can thus effectively manipulate the grain types to suit various end-use qualities.

Information on traditional food uses of sorghum and pearl millet is available (Rooney et al. 1987, Hoseney et al. 1981, Subramanian and Jambunathan 1980). Food quality includes grain quality, processing quality, and culinary quality. Grain quality standards such as moisture, protein content, and flour/grain grades are available for wheat and rice. But such standards are lacking for sorghum and pearl millet because they do not play a significant role in international market systems. Government pricing policies are important from the consumer's point of view because sorghum is costlier than wheat or rice in some developing countries. Since sorghum and pearl millet are important cereals in Africa and Asia, there is an urgent need to establish standards and techniques to characterize their grain quality by breeders, traders, and policymakers. In this report we discuss our experience, current status, and existing problems in evaluating sorghum and pearl millet cultivars in India for foods like *roti*, boiled sorghum, and porridges. The scope and need for further improvement and research to develop laboratory evaluation procedures for processing and food quality, which will be useful in sorghum and pearl millet programs, are indicated.

Grain Characteristics

Physical grain characteristics that contribute to food quality are color, endosperm texture, presence or absence of testa, and hardness, in addition to various

1. Biochemist, and Principal Biochemist and Program Leader, International Crops Research Institute for the Semi-Arid Tropics. (ICRISAT). Patancheru, A.P. 502 324, India.

ICRISAT Conference Paper no. CP 680.

Subrahmanian, V., and Jambunathan, R. 1992. Laboratory procedures for evaluating grain and good quality of sorghum and pearl millet: problems and prospects. Pages 143–150 *in* Utilization of sorghum and millets (Gomez, M.I., House, L.R., Rooney, L.W., and Dendy, D.A.V., eds.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

55h\

Table 1. Tests for routine evaluation of sorghum and pearl millet grains and future research needs.

Factors/tests	Availability of methods	Future research needs	Reference
Grain color	A	NR	Murty et al. 1982
Endosperm texture			
Sorghum	A	NR	Rooney & Murty 1982
Pearl millet	NA	R	
Floaters test	A	NR	Hallgren & Murty 1983
Pericarp thickness	NA	R	—
Germ: endosperm ratio	NA	R	—
Kiya grain hardness test	A	NR	Subramanian et al. 1987
Grain size distribution	A	NR	—
Kernel shape	NA	R	—
Dehulling quality	A	NR	Reichert & Youngs 1976
Particle size index	A	NR	Subramanian et al. 1987
Water absorption grain and flour at 90°C	A	NR	—
Gel spreading test	A	R	Murty et al. 1982

A = Available, NA = Not available, R = Required, NR = Not required.

chemical characteristics. These physical characteristics influence both primary and secondary processing of grains for food. Each food product requires unique grain structure and composition.

Tests for routine evaluation of physical grain characters are listed in Table 1. Local preferences for grain color exist in various regions. White sorghum and pearl millet grains have good potential for bakery products. Sorghum grains are generally uniform in size, although in pearl millet, grain size varies considerably and we have encountered at least six different sizes of pearl millet within the same cultivar. Smaller grains generally have higher bran:endosperm ratios, which is unfavorable for dehulling recovery. Large, uniform, and round grains with hard texture are best suited for optimum dehulling recovery.

Subjective scoring of endosperm for texture (corneous/floury) is well established for sorghum, but not yet for pearl millet. Though corneousness has been used to evaluate grain hardness, this is not a precise technique for comparing cultivars. Grain hardness is still a very difficult parameter to measure and the available methods to determine it require further improvement.

Grain Processing

Dehulling

Dehulling of sorghum or pearl millet grains is a priority problem in many African countries. Mechanical dehulling reduces drudgery in food preparations while rendering the food more palatable and acceptable. Laboratory evaluation showed variation for dehulled grain recovery among sorghums and millets (Reichert and Youngs 1976). The Scott Barley Pearler and Tangential Abrasive Dehulling Device (TADD) have been used successfully for evaluating dehulling quality. Our studies indicate that these two systems of grain recovery are similar. There is a need to compare laboratory evaluation methods with those of batch-type commercial dehullers. Acceptable dehulled grain recovery and a larger proportion of nutrient retention in dehulled grain are desirable when grains are dehulled. Variation in loss of nutrients due to dehulling methods has been reported (Reichert and Youngs 1977). Therefore, a trade-off is needed between nutrient loss and dehulling.

Milling

Grinding grains to a desirable particle size is necessary to utilize the grains for specific foods, and is mostly done by hand pounding. Although the particle size may be manipulated to some extent by grinding or pounding, genotypic variation has been observed. Mechanical production of coarse (*brise*) and fine (*sanxal*) grits has been standardized by the Institut de technologie alimentaire, Senegal, and is being popularized. Laboratory methods are needed to test the cultivars for the production of grits or flour with desirable particle size suitable for the preparation of specific traditional foods. Sorghum and pearl millet cultivars that yield higher proportions of fine flour particles with less starch damage are better suited for bakery products than those with large flour particles and extensive starch damage. Factors like hardness and corneousness of grain play vital roles in the yield of grits/flour particles. It is desirable to subject all advanced entries to a milling test.

Secondary Grain Processing Methods

Secondary processing of grains or flour includes fermentation, malting, extrusion, flaking, and popping. Partial fermentation of pearl millet grain is common for the preparation of *hourou* in Niger. Sorghum flour is fermented before making *kisra* (Sudan) or *injera* (Ethiopia). Preliminary studies in our laboratory indicated that flours of hybrid and local sorghums differ in their fermentation characteristics as determined by swelling volume of the batter.

Malting is used to produce baby food and beer. Malting involves steeping the grain in water, followed by sprouting for up to 96 h. The ability to produce amylases on germination has always been the most important criterion (Novelle 1982). Malter grain is dried at 50°C to reduce the diastase activity. This process has been reported to improve storability and flavor and color of malt. The processing method used during malting significantly influences the diastatic power, and studies are needed to establish whether malted grain (green malt) can be used directly for making fermented porridges/beer without drying. Pearl millet malts are comparable to barley malt in amylolytic and proteolytic activities (Pal et al. 1976), and this similarity needs further exploration.

The possibilities of snack foods from sorghum and millets are excellent, since such products have long shelf life. Flakes made from sorghum generally have poor color, however, and improvement studies are needed to ensure consumer acceptability. Small sorghum grains with white or creamy color, medium-thick pericarp, and hard corneous endosperm are characteristics of popping types. Extruded fat-fried products are commonly produced from rice and wheat flour. Extrusion cooking has good potential for industrial utilization for sorghum and pearl millet.

Food Quality

From the breeder's viewpoint, grain types with desirable agronomic traits and good food quality must be further developed. Each type of food product requires different grain quality criteria. For example, soft wheat with low protein is desirable for cakes and cookies, and hard wheat with high protein is suitable for breadmaking. The International Symposium on Sorghum Grain Quality held at ICRISAT generated valuable information for the classification of traditional sorghum foods and for the identification of various physicochemical grain factors contributing to food quality (Rooney and Murty 1982). A survey conducted in 171 villages in India provided information on various foods prepared from sorghum and pearl millet and their quality criteria (Subramanian and Jambunathan 1980). Similar surveys at village level in Africa and Latin America will be very useful in understanding the requirements of the traditional consumers, the farmers.

Physical Chemical Characters

Food quality is complex and single tests can seldom predict overall food quality. The details of various tests are given in Table 2. It may be observed that the correlation between the quality parameters and physicochemical properties are not always high. It is obvious that several factors complement each other to influence food quality. After two decades of intensive research on wheat chemistry and quality, the microbaking test is still considered the best method of predicting bread quality. However, Finney et al. (1987) reported the use of six important milling and baking parameters to rank soft wheat cultivars for use in food. A value for each of the six quality parameters was assigned and the sum of total values was used for comparison of cultivars. Such a system should be developed for sorghum and millets. Correlations between several characters were worked out in evaluating sorghum and pearl millet foods, but further work is needed to understand the relationships among the characteristics to devise a suitable technique for screening. Rheology and texture measurements of sorghum and pearl millet foods are complicated. Instruments like Instron are precise but very expensive, and further work on standardization is required for sorghum and pearl millet foods. Attempts are needed to study the relationship between Instron values and taste panel results for evaluating food texture.

It is essential that breeders incorporate grain traits for preferred food quality along with agronomic factors contributing to yield. As a routine practice, specific tests as listed in Table 3 should be performed on all breeding lines. Although this list is not exhaustive,

Table 2. Relationship between physicochemical properties and overall food quality of sorghum and pearl millet.

Factors	r value/relationship	Reference
Dough		
Sorghum dough-rolling quality vs floaters (%)	-0.71[1]	Hallgren & Murty 1983
Good quality sorghum dough	Lower gelatinization temperature; higher peak viscosity and set-back values	Desikachar & Chandrashekar 1982
Roti		
Overall sorghum *roti*		Murty et al. 1982
vs water quality absorption (%)	-0.80[1]	
vs gel spread	-0.76[1]	Murty et al. 1982
vs amylose (%)	0.65[1]	Murty & House 1987
Good sorghum *roti* quality	Water-soluble flour fraction, water-soluble protein, amylose	Subramanian & Jambunathan 1987
Sorghum *roti* texture vs starch damage	-0.72[1]	Subramanian & Jambunathan 1987
Pearl millet *roti* quality		
vs swelling capacity of flour	0.81[1]	Subramanian et al. 1987
vs water-soluble flour fraction	-0.87[1]	Subramanian et al. 1987
vs water-soluble protein	0.67[1]	Subramanian et al. 1987
Tortilla		
Sorghum tortilla quality		
vs phenols	-0.50[1]	Murty & House 1980
vs gel spread	-0.66[1]	Murty et al. 1982
To (ugali)		
Sorghum *to* quality		
vs water-soluble amylose	0.58[1]	Murty & House 1980
vs starch granule number	-0.59	Murty & House 1980
Sorghum *ugali* quality vs gel spread	-0.80	Murty et al. 1982
Sorghum porridge quality vs starch damage	-0.85[1]	Subramanian et al. 1987
Good quality sorghum *muddhae*	High gelatinization temperature, low peak viscosity and set-back values	Desikachar & Chandrashekar 1982
Atole	Starch content, gelatinization and dextrinization of starch	Rooney et al. 1987
***Soru* (boiled product)**		
Sorghum *soru* quality score of vs swelling power of starch at 60°C	-0.67[1]	Subramanian & Jambunathan 1987
Pearl millet *soru* quality vs swelling of score starch at 70°C	-0.83[1]	Subramanian & Jambunathan 1987
Soru quality score vs gruel solids	-0.65[2]	Subramanian & Jambunathan 1987
Kisra		
Sorghum *kisra* quality vs gel spread	0.60[1]	Murty & House 1980
Cous cous		
Sorghum *cous cous* yield vs overs	-0.63	Galiba et al. 1985
Sorghum Bread		
Organoleptic evaluation vs evaluation (%)	-0.52[1]	Miller & Burns 1970
Organoleptic evaluation vs amylose (%)	-0.50[1]	Miller & Burns 1970

1. Significant at 5% level.
2. Significant at 1% level.

Table 3. Useful laboratory tests for evaluating processing and end-use properties of sorghum and pearl millet.

Traits	Food Products											
	Roti	*Tortilla*	*Kisra/ injera*	Bread	Cookies	*To/ Ugali*	*Ogi/ rouye*	*Nifro/ soru*	*Couscous*	Sun-dried snacks	Opaque beer	Starch
Tests for grain processing												
Dehulling recovery	3	3	1	1	1	1	1	1	1	1	3	2
Pericarp thickness	3	3	1	1	1	1	1	1	1	1	3	2
Grain hardness	1	1	2	2	2	2	2	2	3			
Prolamin content	3	3	2	2	2	3	3	3	3	3	2	2
TADD test	3	3	2	3	3	1	1	1	1	1	3	3
Milling recovery	1	2	1	1	1	1	1	3	1	1	2	1
Grain hardness	3	3	2	1	1	1	2	2	1	1	2	2
Flour particle size index	1	1	1	1	1	1	1	3	1	1	2	3
Malting/brewing/ fermentation	3	3	1	1	3	3	3	3	1	3	1	3
Prolamin content	3	3	1	2	3	3	3	3	2	3	1	2
Gelatinization temp. of starch	3	3	3	3	3	1	1	3	3	3	1	1
Pericarp thickness	3	3	2	2	2	1	1	1	1	1	1	2
Endosperm texture	1	2	1	2	3	1	1	1	2	2	1	2
Alpha-amino nitrogen	3	3	3	3	3	3	3	3	3	3	1	3
Tannin	3	3	1	1	1	2	2	1	1	1	1	1
Water retention capacity												
Flour swelling capacity	1	3	1	1	1	1	1	3	3	1	2	3
Alkali test (phenols)	1	1	1	1	1	1	1	1	1	1	2	1
Flour particle size	1	3	1	1	1	1	1	3	1	1	2	3
Gel spreading test	1	1	1	2	2	1	1	3	2	2	2	3
Volume changes in batter/ flour granulation	3	3	1	3	3	3	3	3	1	3	3	3
Protein	2	2	2	1	1	2	1	2	2	2	1	1
Water soluble flour fraction	1	2	3	3	3	3	3	3	3	3	3	3
Water soluble protein	1	2	3	3	3	3	3	3	3	3	3	3
Starch damage	1	1	2	1	1	1	1	3	3	2	2	1
Swelling power and solubility of starch	2	2	1	1	1	1	2	1	2	1	2	1
Amylose	1	1	1	2	3	1	1	1	2	1	2	1
Maltose	3	3	3	3	3	3	3	3	3	3	1	3
Visamylographic properties	1	1	1	2	2	1	1	1	2	1	2	1

1 = Important, useful to carry out the test.

2 = Important, further research needed for developing the test.

3 = May not be important; data not available.

TADD = Tangential Abrasive Dehulling Device.

these tests will be useful for evaluating the various food products to fix quality criteria which can be used for developing rapid, simple tests in a breeding program.

Taste Panels and Consumer Preference

Taste panelists must be familiar with the foods they are asked to evaluate. We have encountered difficulties in training panelists at Patancheru (India) because they were unfamiliar with pearl millet *roti*. Pearl millet *rotis* were therefore evaluated at Hisar (India), a major pearl millet-consuming area. Correlation between evaluations at Hisar and Patancheru varied between 0.12 and 0.53 for the various *roti* quality parameters studied. It is best to test the food in locations with the assistance of food research institutes or local universities/institutions where it is commonly consumed.

Consumer panels are different from taste panels. Before a variety or hybrid is released, it should be tested for acceptance as food at the village level by local consumers. Unless the new cultivar is equal or better in quality than the local cultivar, it will not be accepted, even though it may have other favorable attributes such as resistance to diseases and excellent yields.

Sorghum for Starch

Sorghum and maize starches are similar in several of their physicochemical characteristics. Starch properties of sorghum hybrids and high-yielding varieties must be compared with maize in terms of grain properties suitable to industrial starch production. Bold grains with low protein are preferred in the starch industry. Special attention should be paid to developing sorghum cultivars that yield larger amounts of starch as well as better quality starch.

Grain Sampling

A wide variation was observed in the organoleptic properties of *roti* made from grains grown in rainy and postrainy seasons (Murty et al. 1982). Measuring alpha-amylase activity in grains from the rainy-season crop may be useful because it influences food quality. The question arises whether cultivars growing in one location, for example in India, can represent the grains of the same genotype in another location, like Kenya. Therefore, a suitable system needs to be developed to represent the region and the type of food in question. A sample size of 100 g is required for testing physicochemical characters. For comparisons of dehulling quality or organoleptic evaluation, grain quantities of up to 1 kg are needed.

International Testing of Laboratory Methodology

Cooperative tests on cooking properties and amylography of rice were useful in comparing values across different laboratories (Juliano 1985). Collaborative tests for estimating factors like grain hardness, amylography, starch damage, in vitro protein digestibility, and food characteristics can be considered by different world laboratories working on sorghum and pearl millet. Cooperative testing will be useful in relating food quality factors with grain characteristics, including functional quality, and facilitate comparative evaluation across different laboratories, thus improving and defining methodologies.

Strategies for the Nineties

Exploratory laboratory research on the potential utilization of sorghum and pearl millet to assist the breeders and consumers is required. Efforts to identify major quality criteria of foods should continue, taking into account the traditional processes involved. Economically feasible milling technologies to suit the village-level consumer should be developed. Certain important areas for the future research are as follows.

- Basic breeding work on heritability of grain factors relating to milling, particle size distribution, and food quality.
- Starch-protein interaction, gelatinization characters, food rheology, and texture.
- Storage quality of flour and foods.
- Utilization of high protein, high lysine lines for developing baby foods and protein digestibility.
- Identification of bird-resistant high-tannin sorghum with hard grain to withstand dehulling.
- Grain quality standards for industrial uses: for example, starch, malting, brewing, and baking.

Summary and Conclusions

Laboratory evaluation of grains for food quality must form an integral part of any crop breeding program.

There is an immediate need to develop suitable processing technologies for sorghum and pearl millet to enhance consumer acceptability and develop alternative uses. Basic studies on physicochemical properties of the grain that relate to food quality are important and useful.

While developing high-yielding lines, breeders must incorporate traits essential in acceptable traditional foods, good processing qualities, or industrial products. Multidisciplinary research teams involving plant breeders, food technologists, cereal chemists, socioeconomists, home economists, and industrialists are necessary to achieve these goals.

References

Desikachar, H.S.R., and **Chandrashekar, A.** 1982. Quality of sorghum in Indian foods. Pages 262-268 *in* Proceedings of the International Symposium on Sorghum Grain Quality, 28-31 Oct 1981. ICRISAT Center, India. Patancheru, A.P. 502 324, India. International Crops Research Institute for the Semi-Arid Tropics.

Finney, P.L., **Gaines, C.S.**, and **Andrews, L.C.** 1987. Wheat quality: a quality assessor's view. Cereal Foods World 32:313-319.

Galiba, M., **Rooney, L.W.**, **Waniska, R.D.**, and **Miller, F.R.** 1985. Another *cous cous* quality criterium measuring large gelatinized pieces. Sorghum Newsletter 28:28-29.

Hallgren, L., and **Murty, D.S.** 1983. A screening test for grain hardness in sorghum employing density grading in sodium nitrate solution. Journal of Cereal Science 1:265-274.

Hoseney, R.C., **Varriano-Marston, E.**, and **Dendy, D.A.F.** 1981. Sorghum and millets. Pages 71-144 *in* Advances in cereal science and technology, Vol. VI, (Y. Pomeranz, ed.), American Association of Cereal Chemists Inc, St Paul, Minnesota, 1981.

Juliano, B.O. 1985. Cooperative tests on cooking properties of milled rice. Cereal Foods World 30:651-656.

Miller, O.H., and **Burns, E.E.** 1970. Starch characteristics of selected grain sorghums as related to human foods. Journal of Food Science 35:666-668.

Murty, D.S., and **House, L.R.** 1980. Sorghum food quality: its assessment and improvement. Paper presented at the Fifth Joint Meeting of the UNDP-CIMMYT-ICRISAT Policy Advisory Committee, 14-18 Oct 1980. ICRISAT Center, India. Patancheru, A.P. 502 324, India : International Crops Research Institute for the Semi-Arid Tropics. (Limited Distribution).

Murty, D.S., **Patil, H.D.**, and **House, L.R.** 1982. Sorghum roti. II. Genotypic and environmental variation for roti quality parameters. Pages 79-91 *in* Proceedings of the International Symposium on Sorghum Grain Quality. 28-31 Oct 1981. ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

Novelle, L. 1982. Fermented Beverages. Pages 113-120 *in* Proceedings of the International Symposium on Sorghum Grain Quality, 28-31 Oct 1981. ICRISAT Center, India. Patancheru, A.P. 502 324, India: International International Crops Research Institute for the Semi-Arid Tropics.

Pal, A., **Wagel, D.S.**, and **Sheorain, V.S.** 1976. Some enzymatic studies of bajra (*Pennisetum typhoides*) and barley (*Hordeum vulgars*) during malting. Journal of Food Science and Technology 13:75-78.

Reichert, R.D., and **Youngs, C.G.** 1976. Dehulling cereal grains and grain legumes for developing countries: a quantitative comparison between attrition and abrasive type mills. Cereal Chemistry 53:829-839.

Reichert, R.D. and **Youngs, C.G.** 1977. Dehulling of sorghum food quality. Pages 571-588 *in* Sorghum in the eighties: proceedings of the International Symposium on Sorghum, 2-7 Nov 1981, ICRISAT Center, India. Vol. 2. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Rooney, L.W., **Kirleis, A.W.**, and **Murty, D.S.** 1987. Traditional foods for sorghum: their production, evaluation, and nutritional value. Pages 317-353 *in* Advances in cereal science and technology, vol VIII (Y. Pomeranz, ed.), American Association of Cereal Chemists Inc, St Paul, Minnesota, 1987.

Rooney, L.W., and **Murty, D.S.** 1982. Evaluation of sorghum food quality. Pages 571-488 *in* Sorghum in the eighties: proceedings of the International Symposium on Sorghum, 2-7 Nov 1981, ICRISAT Center, India. Vol. II. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Subramanian, V., and **Jambunathan, R.** 1980. Traditional methods of processing sorghum (*Sorghum bicolor* [L] Moench) and pearl millet (*Pennisetum americanum* L.) grains in India. Reports of the International Association of Cereal Chemists 10:115-118.

Subramanian, V., **Jambunathan, R.**, and **Prasada Rao, K.E.** 1987. Dry milling characteristics of sorghum grains and their relationship to product quality. Pages 45-54 *in* Proceedings of the National Seminar on Technology and Applications for Alternative Uses of Sorghum, 2-3 Feb 1987, Marathwada Agricultural University, Parbhani, India.

Subramanian, V., and **Jambunathan, R.** 1987. Grain quality of sorghum, pearl millet, maize and minor millets. Paper presented at the Symposium on Present Status and Future Perspectives in Technology of Food Grains, 27 Feb to 1 Mar 1987, Central Food Technological Research Institute, Mysore, India.