Uses of Sorghum and Millets

Summary Proceedings
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8-12 February 1988

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Uses of Sorghum and Millets

Summary Proceedings of an International Workshop on Policy, Practice, and Potential Relating to Uses of Sorghum and Millets held at Bulawayo, Zimbabwe 8-12 February 1988

International Crops Research Institute for the Semi-Arid Tropics

SADCC/ICRISAT Sorghum and Millet Improvement Program

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Workshop Organizers

M.I. Gomez
L.R. House

Scientific Editors

D.A.V. Dendy
M.I. Gomez
L.R. House
L.W. Rooney

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Preface

The SADCC/ICRISAT Sorghum and Millet Improvement Program hosted an International Workshop on Policy, Practice, and Potential Relating to Uses of Sorghum and Millets during 8-12 February 1988 at Bulawayo, Zimbabwe.

The main purpose of this workshop was to explore opportunities for expanding crop utilization of sorghum and millets. Experts from several disciplines and industries took part. As the crops have great diversity in usage, emphasis was placed on priorities among products, so that selection criteria can be established for breeding improved varieties and hybrids. Identification of regional crop use opportunities, both short-term and long-term, formed part of an overall effort to gain an integrated perspective.

Presented in this summary volume are: (1) speeches at the opening session, which set the tone for the discussions; (2) the recommendations that emerged at the workshop; (3) abstracts of 26 papers that contributed to the discussions; and (4) a list of those who took part.

We plan to publish a full proceedings, to include detailed papers, at a later date. Work on processing these has begun. It is hoped that this will be a useful addition to existing literature in this area.

In the interim, this summary volume can be a signpost of the directions indicated for research and development efforts aimed at better utilization of sorghum and millets. Such utilization can play an important role in many national economies of the semi-arid tropics.

L.R. House
Executive Director
SADCC/ICRISAT Sorghum and Millet
Improvement Program

Opening Session

Objectives of the Workshop

L.R. House

Executive Director,
SADCC/ICRISAT Sorghum and Millet Improvement Program,
P.O. Box 776, Bulawayo,
Zimbabwe

Although this is not an objective, I wish to begin by expressing my appreciation of the contribution that Mrs Manel Gomez has made to this conference. She has been working steadily for many months, providing both technical and logistical input . The success of this conference is due to her insight and determination.

The system of International Agricultural Research Centers began with the International Rice Research Institute in 1962. There are now 13 Centers, and their focus has been very much on the production of food. In recent years, India and China have become self-sufficient, even exporting food grains. Zimbabwe consistently has surplus and exports. Nigeria, Malawi, and Zambia are at times excess. There is a general recognition of the importance of expanding opportunities for crop utilization. ICRISAT, too, in this context, wants to develop a global strategy in food technology and crop utilization.

Sustainability of production is a much-heard phrase these days. Diversification of agriculture—involving crops, livestock, and agroforestry—is relevant, as is improving market opportunities.

The primary objective of this conference is to gain an appreciation of how sorghum and millets have been used. There are many products, and more than one product is possible from a single crop. Sorghum and millets have great diversity; and, with a recognition of priorities among products, selection criteria can be established so that varieties and hybrids can be developed with end uses in mind. We wish, in this conference, to agree on priorities among products to help give direction to crop improvement activities. Priorities for crop uses will vary from location to location, and this should be reflected in our discussions.

We recognize that there are short-term and long-term objectives. For example, we have tests useful to evaluate thick porridge made from grains of different sorghum varieties. Looking to the future, is it possible to sufficiently increase feedlot activity to reduce damaging livestock pressure on the range?

We feel that the market is so dynamic that prices and policies are apt to change before there is substantial contribution from research and development. For this reason, we encourage participants to express basic ideas, ignoring current price/policy issues or constraints.

We have a specific interest in sorghum and millets, but we recognize that developments with other crops may be relevant. I understand, for example, that about 30% of the paper pulp in Denmark includes straw from small grains. The Carlsberg Lab is using rape and stem material to make a construction board. Sorghum and millet straw may well be used for such products.

Petrol in use in Zimbabwe and Malawi is a blend with alcohol from sugarcane. Alcohol can be produced with equal efficiency from sweet-stemmed sorghum, and sorghum may have advantages as a companion crop with cane.

This meeting has three main divisions: food, traditional and industrial; feed; and nonfood industrial uses. People at this meeting come from public research agencies and the business community. Backgrounds and interests are widely divergent, to a degree, reflecting area-specific crop uses. One objective of this meeting is to share experiences, rather than to present findings from some specific piece of research. We hope that your experiences will be expressed and shared during the course of this meeting. There are participants from far away and participants from Zimbabwe. We hope that you will interact with each other to improve understanding of what each is doing and can do.

There are two major sections to this meeting. The first consists of papers, which have the objective of describing the array of experiences / activities of the speakers. We hope that this will help all participants to broaden their perspective of crop utilization. During the second part of the meeting, we will divide into a number of smaller working groups. You have been given a discussion format that we anticipate can be followed in these groups. Please look at this format, both to be familiar with it and to comment about it. This approach is new to us, and your suggestions to make it better will be welcome.

We have suggested that some of the participants contribute to a discussion group where they have expertise. Some other participants have not been so assigned, and they can participate according to their interest. Individuals who would like to participate in more than one group can divide their time. We also hope that participants will interact individually with each other during the meeting. At the end, there will be a plenary session where representatives from each group will present their conclusions to all participants.

ICRISAT plans to have a proceedings of this meeting. Dr Mohan Raj, editor with ICRISAT's Information Services, is here and will want to interact with the speakers during the week.

I hope that the meeting will proceed well and that you will all feel free to participate in a way we can all benefit from the meeting.

Opening Address

S.C. Muchena

Deputy Secretary (Technical), Ministry of Lands, Agriculture, and Rural Resettlement, Government of Zimbabwe

Mr Chairman, Ladies, and Gentlemen:

It is my great honor to greet you all and welcome you to Zimbabwe and this workshop. I know some of you have traveled long distances to attend this important International Workshop on Policy, Practice, and Potential Relating to Uses of Sorghum and Millets.

The utilization of sorghums and millets, or traditional small grain crops as we sometimes call them, is a topic of great interest to me. I remember one evening towards the end of 1982 or beginning of 1983 when Ozzie Schmidt and I sat in a hotel room in Harare discussing plans to promote utilization of small grains through a SADCC regional project. We had different interests which converged nicely. He was interested in them as a vehicle for rural development. I was interested in them from a different angle altogether. I had been involved in breeding these crops and had naturally developed an extraordinary attachment to them. Soon after my meeting with Ozzie, I found there were a number of other interested individuals. I feel 1 must mention in particular Professor Carl Eicher from Michigan State University, who was visiting professor at the University of Zimbabwe. Among many ideas, we discussed small-grain processing and utilization. I never thought 1 would have so much compatibility with an economist, but somehow we agreed in many respects. I have always teased the economists on the assumptions they make.

Many individuals from the region and from premier institutions outside it have contributed to the currently crystallized concern with small-grain production, processing, and utilization. Some of them are here at the workshop. In the interests of brevity, I will just name Mrs Manel Gomez, Dr David Dendy, Dr Lee House, Mr Charles Gore of the Environment Development Agency, Mr Joe Mushonga and his colleagues, Mr R. A. Bull, the Canadian High Commissioner in Zimbabwe, and Dr Joe Hulse.

A critical mass of small grains researchers, developers, and promoters has been thus established in this country, and indeed in the SADCC region. The main organizer of this workshop, Mrs Manel Gomez, owes us an explanation. How does one get together such a distinguished gathering in 3 months ?

Before I proceed further, I would like to give you some basic information on Zimbabwe and the SADCC region as a whole.

First of all, we are part of the sub-Saharan region, on which a number of conferences, workshops, symposia, and meetings have been held, focusing on the food security crisis. We have seen various proposals put forward to address the recurrent imbalance between food production and the ever-growing population. To quote specific figures from FAO , food production increased approximately 1.9% per year between 1961 and 1980. Countering this progress is a nearly 3% per year increase in population over the same period, resulting in a decline of 1.1% in per capita food production. According to recent FAO figures, the sub-Saharan food scenario continues to deteriorate. Our imports of food are on the increase.

Most analyses of Africa's decline have focused on drought, the disarray of national economies, and the continent's tumultuous politics. Few have recognized that a new approach to development is required—a resource-based strategy.

A large percentage of the SADCC region lies within areas of marginal rainfall, where rainfall is usually less than 600 mm and unevenly distributed. The proportion of land that falls under areas of marginal rainfall varies from country to country (for example, 5% in Zambia, 77% in Zimbabwe, and 100% in Botswana). Recently the region has suffered from drought years. In this decade alone, 5 of the 7 years so far have been drought years.

Sorghum and millets, being drought resistant, are the most suitable crops under rainfed conditions. However, maize, a drought-susceptible crop, is now grown more widely than the small grains. There are various reasons for this:

- Maize is more resistant to bird damage.
- Maize yields are higher when the rainfall is good.
- Maize is easier to process.

Past government policies, too, established a demand in the domestic cash economy for maize production. Another reason given to explain the dominance of maize, that it is more palatable, has recently been proven incorrect. A National Market Test for small-grain meal in Zimbabwe revealed that 45% of respondents preferred pearl millet meal and 31% preferred sorghum meal, while only 6% preferred maize meal. The remaining 18% had no preference. In another test, 51% of the respondents preferred sorghum, 35% preferred pearl millet, 10% preferred maize, and 4% had no preference. It is thus apparent that factors other than palatability led to the dominance of maize in areas of marginal rainfall. Probably most important is the drudgery involved in the processing of small grains.

Governments in the SADCC region have become increasingly concerned over the general trend away from the production and consumption of sorghum and millets in favor of maize.

It is believed that elimination of the processing constraints will lead to reversal of that trend, which came about from the beginning of this century when maize gradually became the predominant crop even in areas where it is least suited. Greater production of traditional grains should lead to better national and household food security because the traditional crops are hardier and more nutritious. We believe plant breeding efforts in these crops should lead to enhancement of these attributes.

For these reasons, there have been efforts in Botswana, Zimbabwe, and other SADCC countries to introduce dehuller technology. The objectives for introducing this technology are not merely to promote domestic production and consumption of sorghum and millets, but also to raise the value of agricultural production, thus reducing dependency on imports, and to promote rural development by raising employment, productivity, and income levels. Let me, at this juncture, state the SADCC objectives for the Food, Agriculture, and Natural Resources Strategy developed in 1986, which is in line with the Lagos plan of action. The strategy aims to:

- Provide a framework to integrate SADCC's regional and national policies and projects, and to harmonize investments that cut across sectors such as agroindustry and human capital improvements.
- Reinforce and facilitate the efficient growth of food and agricultural production in member states and to encourage intraregional trade.
- Increase rural income and facilitate employment generation in member states, in order to help translate the food needs of rural people into effective demand for purchase of food in the market.
- Assist member states in designing policies, programs, and projects to increase household food security and ensure an adequate diet for all members of society.
- Increase national and regional food security, to ensure against bad harvests and natural diasters and to reduce dependence on South Africa and other sources.
- Foster the efficient development, utilization , and conservation of natural resources and the protection of the environment.
- Generate domestic savings and foreign exchange to finance a gradual structural transformation of agriculture-dominated economies into those producing a larger percentage of industrial goods and services.

One cause for poverty in Africa is the use of inappropriate technology. As the Nigerians say, we must laugh with the teeth we have, even if they are very few. The future development of this continent will much depend on the selection and use of raw materials and technologies suited to particular needs and resource endowments. I feel small grains have a major role to play in the development of our rural economies. We have thus far made limited use of them. I believe out of your workshop new ideas on utilization will emerge.

I talked a little about a critical mass of professionals necessary to achieve sufficient momentum to mobilize resources for utilization of small grains for rural development. The next step would be the establishment of a tradition in small grains research, processing, and utilization. To establish a sustained tradition, training of manpower is vital. Fully trained manpower in food science and technology will be required to carry out work in administration, research, development, standardization and control, education, and extension.

The provision of trained personnel, capable of carrying out these functions, can be achieved through degree programs in food science, technology, and nutrition at both undergraduate and postgraduate levels under specialized university departments. It is gratifying to note that this is already taking place.

I notice on your information sheet that there are some suggestions for sightseeing. Do not hesitate to stay on beyond the workshop period and enjoy our country. However, should you decide to stay much longer, remember the Swahili saying: "Mugeni ni mugeni siku moja, siku pili, siku ya tatu mupatiye jembe". This literally means after a visitor has been around for a couple of days, he or she should be given work to do.

Lastly, Mr Chairman, I would like to wish you a successful and fruitful week. With these few remarks, I declare your workshop open.

Recommendations

Food, Primary Processing

1. There is need to recognize and develop differential quality requirements of sorghum for traditional and commercial primary processing. For example, traditional dehulling preference is for thick pericarp, soft/intermediate endosperm grains, while commercial abrasive hulling/milling requires thin pericarp, vitreous grain. Processing research is needed to optimize traditional technologies with regard to degree of conditioning for maximum milling yield, period of presoaking/pregermination, maximum removal of tannins, etc.
2. Several mechanical hulling/milling systems—such as modified wheat milling (for example, Bhuler Miag) , abrasive dehulling (+ hammer/ roller milling) , conditioning + impact (such as those used by United Milling Systems), and semiwet milling—have been developed to the R & D and semi-industrial stage. Systematic comparative evaluation of hulling/milling performance of these systems (extraction rate, etc.), based on selected check varieties, is needed. Collaborative studies should be initiated.
3. Differential studies should be initiated on breeding/selection and processing systems for (a) porridge meal, and (b) baking flour and other milling fractions, such as semolina and grits.
4. Further research is needed on nutritional implications of traditional processing methods, notably acid/alkali treatments and possibilities of application on an industrial scale for treatment of sorghum grain as well as bran. This can be significant in extending the use of high-tannin brown sorghum grains for food.
5. Pearled sorghum rice analogue has reached the R & D and test marketing stage in several countries, such as Sudan, Kenya, and Botswana. Quality standards are still not optimized for color, grain size, texture, cooking quality, etc., in relation to appropriate varieties. Selection pressure is needed. Rice analogue is an important commodity in SADCC countries that do not grow rice.
6. Malting is an important process, not only for production of opaque and clear beer but also for food malts and weaning foods based on improved nutritional quality of malted grain. Grain selection in sorghum and millets for good malting quality is a high priority in the SADCC region, as well as in West and eastern Africa. Breeding and processing research need to be intensified for identifying grains with high diastatic units and high free amino nitrogen (for brewing malts), and those with moderate diastatic units and good flavor profile (for food malts).
7. Methodologies need to be standardized for quality evaluation, such as micromalting and diastatic activity determinations through interlaboratory trials on selected check varieties of sorghum and millets.
8. Research is needed to extend application of processing technologies, such as flaking and micronization, to human foods and to optimize these processes for cost efficiency and nutritional and food quality.
9. Industrial processes, such as extrusion cooking, need to be explored as sources of pregelatinized sorghum flour and complementary cereal/legume precooked mixtures, such as *Soyogi* in West Africa. Extrusion cooking capacity is now established in Botswana and Zimbabwe.

10. Chewing sorghums are widely consumed throughout the SADCC region, though their relative importance in diets is unknown. Industrial use of sweet sorghum for sugar and alcohol is not a high priority for the SADCC region but, where feasible (Brazil), selection for high sugar, low fiber, high extractability, and multiple ratooning is needed.
11. Introduction of high-lysine sorghums for milk/dough/hard stage consumption (as in Ethiopia) should be explored in the SADCC region. Acceptability should be tested, based on better flavor/palatability, but as a matter of medium to low priority.
12. **Methodologies.** There is a need to standardize several of the physical, chemical, and functional quality testing methodologies, such as for grain hardness, tannin content, dough quality (rheology), and digestibility tests, through interlaboratory evaluations on a range of check varieties, representing low, medium, and high points on the respective quality scales.

There is a similar need to standardize terminologies regarding color descriptors, high and low tannin quantification, etc., and related qualitative descriptions should be measurable in a standardized way (for instance, hardness can be measured on an instrumental scale, milling yield scale, or particle size index scale). Implied in this is the need to identify a network of laboratories, with capabilities to cooperate in this endeavor and representing resource capabilities in specific areas.

A consensus was expressed that the SADCC/ICRISAT Regional Program should serve as a reference and coordinating center of such activity for the SADCC region.

Food, Secondary Processing

1. Composite flour technology for production of a range of products, bread, cookies, biscuits, and pastas, incorporating sorghum and millet flour, has been developed in many countries, including SADCC countries such as Zimbabwe. In wheat-importing countries, sorghum/millet based composite products are a high priority. Selection of varieties, which show good milling/baking/extrusion characteristics and with favorable policy/pricing, is desirable.
2. Countries with no or low wheat production should direct breeding and processing research to nonwheat products such as 'bread', biscuits, etc. But the feasibility of nonwheat products is considered low in most SADCC countries, unless, as in Nigeria, wheat is not available at all. This recommendation is, therefore, given a low priority.
3. Soft and hard (thin and thick) cereal porridges are consumed throughout Africa. Considerable research relating grain quality to porridge quality is already available. More work is needed on a pilot scale to develop a ready-to-cook sorghum and millet porridge meal. Organoleptic problems with millet flour need to be studied, to determine whether they can be solved by varietal improvement and/or processing.
4. R & D and semi-industrial scale studies in Nigeria and Mexico have demonstrated the feasibility of 100% replacement of barley malt with sorghum malt in clear beer.

There should be selection pressure for identification of varieties with high diastatic units for this purpose. This application is a high priority in countries dependent on imported barley malt and enzymes. It is a high priority for the SADCC region generally, and medium-to-low for Zimbabwe, which has export capacity for barley malt.

5. Opaque beer, based on sorghum malt, is a traditional product in eastern and southern Africa. It is already commercialized in southern Africa. The product is a high-priority item as both food and beverage, but the technology still needs to be optimized, especially with regard to organoleptic and nutritional quality . Screening of both sorghum and millet varieties for good malting, gelatinization, and organoleptic quality is needed to extend the technology in SADCC countries. Grain and product quality needs to be researched, such as f o r acid fermentation in fermented porridges, which are widely consumed in the SADCC region.
6. Low bulk, nutritionally adequate weaning food is a high priority for all of the SADCC region. Some research has been initiated in the region, as in Tanzania, but more R & D is needed to develop practical, low-cost weaning food formulations that include malt as the bulk-reducing agent. Both traditional use and commercial application need to be encouraged.

Feeds

1. Development is needed of dual-purpose sorghum varieties with improved forage quality and low-tannin grain, as a high priority.
2. Alternative methods of bird control should be studied. Bird bait systems, where small plots of sorghum are planted near roosts to divert birds from large-scale production plots, are working in Zimbabwe. These are combined with spraying very effectively.
3. Breeding and research efforts to improve digestibility of sorghum grain should receive support. The genetic variation in sorghum germplasm should also be assessed for heritable variation in Landry Moreaux Fraction HI storage protein. Improved varieties should be developed.
4. For use as high-moisture green forage, breeding efforts should be directed to interspecific hybrids, such as *Sorghum bicolor* * S. *Sudanense* and *Pennisetum glaucum** P. *purpureum,* to forage cultivars that ratoon, and to improving nutritive quality in preference to yield. However, forage potential for smallholder cut-and-carry systems may not be sustainable where there is competition with food crops.
5. Crop residue utilization, on the other hand, is highly applicable to existing small-scale as well as communal f a r m i n g systems. The importance of crop residue as feed, fuel, construction material; and as an industrial raw material should be considered as a high priority in crop improvement programs.
6. Dual-purpose varieties with greater nutritive value of the crop residue for ruminants should be developed.

7. The economic and ecological impact of the increased use of crop residues for feeding livestock, in competition with other uses, should be determined.
8. A high priority should be given to exploring sources of alkali salt for treatment of high-tannin sorghum grain and bran to improve the feed efficiency of these materials for ruminant and monogastric feeds, and to determining the nutritive value and levels of grain and bran that can be incorporated into feeds. The economic implications of the use of bran from tannin-containing sorghum should be determined for the use of these sorghum varieties by the milling industry.
9. The introduction of the brown midrib mutation and other genetic manipulations that reduce the effects of lignin on forage digestibility should be studied.
10. Further research on the positive effects of tannins in sorghum bran on protein utilization by ruminants—especially by dairy cattle—should receive priority, in order to extend the feed value of high-tannin brans.
11. The pricing policy for sorghum and millet, as well as other cereals, should be consistent with the biological and economic value of the crop.
12. Swine and poultry producers will be important consumers of sorghum and millet in the SADCC region, and crop improvement efforts should consider the use of grain in diets of simple stomach livestock, in addition to cattle diets.
13. The use of sweet, juicy-stem varieties of sorghum in forage production systems should be considered. Consideration of sweet, juicy-stem types against nonsweet, dry-stem varieties may be useful.
14. Priority ought to be placed on evaluating opportunity costs and returns to the use of sorghum and millet stover, grain, and bran for feeding draft animals before the planting season to improve draft quality.
15. There is a need to explore opportunities and constraints relating to the use of feeds based on sorghum and millet, including forage and grain for fattening the cattle of small farmers for market sales, and to evaluate opportunities for stall or pen feeding strategies. This could form a potential basis for increasing small-farm incomes in the semi-arid zones.
16. Guidelines should be established for price and market adjustments that are necessary to stimulate greater use of sorghum and millet products in the formal and informal (farm-based) feed industry.

Nonfood Industrial Uses

1. **Sweet sorghum milling.** In many countries of the world, there is a deficit of fuels and/or ethyl alcohol for industrial use. Technology has been developed for the extraction of the sugar from sweet sorghum biomass and for its transformation into alcohol. Depending upon the demand and price of alcohol, this becomes a profitable enterprise with valuable byproducts: grain, bagasse, and stillage. The grain has the same value as any other grain and may be utilized as a food or feed. The bagasse and stillage may be transformed into biogas and biofertilizer in energy-deficient regions. In this transformation of bagasse to biogas, animals may be used by feeding them the bagasse and using the manure to fuel the biodigester. The biofertilizer should be returned to the soil to maintain fertility.

Improvement of cultivars should be made for maximum alcohol production and maximum biological value of the bagasse for animal forage.

2. **Sorghum crop residue for biogas production (alcohol not an objective).** In many regions, there is a shortage of energy for domestic uses and, as in some circumstances in Botswana, a shortage of energy to pump water for animal use. Sorghum residue can be used as the biomass source in a biodigester for production of biogas. The technology for this process already exists and is available. Sorghum can be improved to have more carbohydrates in the stalks (residue) to improve the yield of this process (sweet stalk type). This should not reduce the potential of grain production.
3. **Dry milling of grain.** Industrial starch is important and is already well-commercialized to make such products as adhesives, as a core binder for well drilling, and in ore refining. As there is good potential for uses such as these, breeders should select grains that have good dry-milling characteristics.

   There is, in Zimbabwe for example, a demand for waxy starch. Existing waxy endosperm hybrids and varieties should be evaluated for industrial use and, if promising, bred for high yield.
4. **Wet milling.** Sorghums with the potential for wet milling to produce starch should be developed as part of the improvement program. Potential for use of waxy sorghum exists in certain areas. Sorghums for wet milling would have intermediate texture, yellow and perhaps waxy endosperm. This is not, however, a high priority.
5. **Dry milling of straw.** The products are fuel pellets, particle and building boards, and cellulose pulp for the paper industry. Research has been conducted on cereals other than sorghum. No pilot research and no industrial/commercial application exists for sorghum straw.

   Sorghum is known to produce an extremely high amount of biomass, and it could be an important renewable energy resource. Fuel pellets can be produced from a meal obtained by dry milling. This meal consists of leaves, nodes, and pith. Another product obtained by the mechanical separation is a fraction from internodes. This fraction is high in cellulose and lignin, and chips could be used in particle and building boards or as raw material for the paper pulp cellulose industry. All writing and printing paper produced in Denmark contains an average of 30% bleached wheat and rye straw cellulose. Sorghum straw could be explored as an alternative.

   R & D is needed to obtain raw materials which, during dry milling, produce optimal fractions for those three products. This can be done in a collaborative study with Carlsberg Research Laboratory, where laboratory equipment is available.

Abstracts

Evaluation of Cultivar Characteristics, Milling Properties, and Processing of Sorghum for Food Use as a Boiled Whole Grain

R.B.H. Wills, *Dept of Food Science and Technology, University of New South Wales, P.O. Box 1, Kensington,NSW 2033, Australia* and

M.R. Ali, *Metabolic Research Laboratory, St Goran Hospital, Fincen Huset, Stockholm, Sweden*

The results of a study to determine the suitability of a wide range of high-yielding sorghum cultivars for food use as boiled whole grain are presented. Considerable variation in grain size within cultivars was found to be common, but this was undesirable because the milling of mixed-size batches had a marked detrimental effect on milling characteristics and yield. Cooking time varied with the extent of milling and was related to the type of endosperm, but it generally remained longer than for rice. Presoaking in water or treatment with alkali reduced cooking time to some extent. While existing hybrid cultivars are suitable for use as boiled grain if proper milling and cooking techniques are utilized, such usage would benefit by breeding programs that develop cultivars with the desired traits.

An Analysis of Progress and Achievements in Regional Dehulling Projects[1]

O.G. Schmidt, *Programme Officer, Postproduction Systems, International Development Research Centre, Regional Office for East & Southern Africa, P.O. Box 62084, Nairobi, Kenya*

The paper characterizes two interrelated problems facing the SADCC countries and inhabitants of their dry areas, and it proposes two developmental objectives: maximum utilization of the potential of the dry areas, and attainment of household food security. Home dehulling of sorghums and pearl millets, important food crops for the dry areas, is one step in primary processing which has presented a problem. The relevance of mechanical dehullers to the food systems of these drought-resistant grains is discussed. The evolution of small-scale dehulling technology is described, and a program for its development and field testing, leading to wider dissemination in sub-Saharan Africa, is summarized. The experiences of that program of research support for processing and utilization, aimed at rural beneficiaries, are brought out by examining the question: what has changed in, and what has been learned about, the postproduction systems of sorghums and millets. The main issues which arise therefrom are identified and briefly discussed. Priorities are identified for future work in the region on sorghum and millets for human food.

1. In the absence of the author, the paper was presented by T. Rukini.

Wet Milling and Nixtamalization of Sorghum

L.W. Rooney, *Professor, Food Science and Agronomy, Texas A &M University, College Station, TX 77843, USA*

Sorghum (250000 t a^{-1}) was commercially processed by wet milling into starch, oil, and feed byproducts from the 1940s to the 1970s at Corpus Christi, Texas. The wet milling properties of sorghum are similar to those of maize. However, a few subtle differences changed the economics and the wet milling plant was closed. Sorghum starch and oil are nearly identical to maize starch and oil. Sorghum is slightly more difficult to wet mill than maize—the recovery of starch is lower. The phenolic pigments of red sorghum affect color of the starch, and the sorghum gluten did not contain sufficient carotenoid pigments to command premium prices from the broiler industry. However, certain sorghum hybrids, i.e., those with yellow endosperm, white pericarp, and tan plant color, had outstanding potential for wet milling. Waxy, yellow endosperm sorghum hybrids had good potential. The technology is available, but the relative cost of sorghum to maize is critical. Sorghum must be lower in price than maize before it can be used.

Nixtamalization is the conversion of maize into tortillas by cooking and soaking maize in alkali ($Ca[OH]_2$) or the leachate of wood ashes. The cooked maize (Nixtamal) is stone ground into masa, which is formed into flat "pancakes" that are baked into tortillas. This process originated in Mexico where maize tortillas are the major staple bread. Sorghum is used for tortillas in Central America, Honduras, Salvador, etc., and on a limited basis in southern Mexico. Sorghum for tortillas would have thick white pericarp, tan plant color, and an intermediate texture. Maize and sorghum mixtures are often utilized. The nixtamalization process is a potential way of producing new products in other areas where corn and sorghum are consumed.

Semiwet Milling of Red Sorghum—A Review

J.E. Cecil, *Overseas Development Natural Resources Institute (ODNRI), Storage Department, Culham, Abingdon, Oxon OX 14 3D A, United Kingdom*

Semiwet milling is a technique discovered and developed by the author at the Overseas Development Natural Resources Institute (ODNRI) for milling various tropical grains. In this method, moist sorghum, containing about 26% of water equilibrated through the grain, is milled on standard wheat-milling equipment. Excellent results were obtained using a laboratory mill, which had been set up for milling wheat. No alterations or major adjustments were made to the mill. A good yield of fine flour, containing very little tannin, was produced from the grain of every variety of sorghum tested, including red, white, and broomcorn cultivars. In most instances, the flour was white. The flours were cooked in various ways. The products had a smooth but slightly chalky texture. In informal taste tests, virtually no taste of tannin was detected. Tests on the laboratory mill have shown that the method is widely applicable, but they have highlighted some limits and defined some limitations. Tests on a commercial mill are now necessary and are planned for 1988. The ability to remove tannin from high-tannin varieties in a conventional roller mill may encourage wider cultivation of pest-resistant varieties, and it could permit utilization of currently unusable cultivars. The ability to produce high-quality flour could open new markets for sorghum, in urban households, in foods currently based on other grains, and in entirely new foods.

Organoleptic Implications of Milled Pearl Millet

R.C. Hoseney, *Kansas State University, Dept of Grain Science and Industry, Manhattan, KS 66506, USA*

The characteristic mousy, acidic odor generated in ground pearl millet during brief storage was investigated and found not to be associated with oxidative rancidity of kernel lipids. Odor generation required relatively high moisture levels in the grits, suggesting that the process is enzymatic. Fractionation and reconstitution experiments showed the odor precursor to be extractable with methanol (but not petroleum ether) and retained on C-18 reverse-phase preparatory columns. When the methanol extract was further separated into water-soluble and water-insoluble fractions, the water-soluble fraction retained the ability to support odor generation. Ultraviolet scans of this active water-soluble fraction showed absorption maxima similar to apigenin, the aglycone of the major C-glycosyflavone present in pearl millet. The characteristic odor associated with storage was formed when apigenin was added to methanol-extracted millet grits.

Status of the Sorghum Milling Technology at Rural Industries Innovation Centre, Botswana

S. Dinat, *Business Manager, Rural Industries Innovation Centre, P. Bag 11, Kanye, Botswana*

The paper attempts a brief historical account of the development of sorghum milling technology at the Rural Industries Innovation Centre (RIIC), Botswana, and the development of a marketing strategy. It follows the production sequence that resulted in the successful transfer of the technology to the private sector in Botswana. The well - worn "extension-cycle" of field needs being fed back to design, production , and marketing managers was met; this helped to continually update and orient the technology to the needs of the end-user rather than the research center. Results from the field over a span of years resulted in further technical updating of the machinery. The

paper also cites the problems encountered in researching and developing a rural-based technology, outlines the support structures required to implement a small-scale agroindustrial program, and expresses the need for a regional market outlook to support and strengthen technology development in the region. Trading results and throughput figures of a typical, small commercial mill are analyzed to support the present parameters on machine size and performance, and a broad overview of the current milling industry in Botswana is given, to indicate the impact of the RIIC sorghum technology. The paper looks at the potential for alternative uses of the machinery, in relation to the alternative uses of sorghum and millets.

Sorghum Malt/Adjunct Replacement in Clear (Lager) Beer: Policy and Practice in Nigeria

O.A. Koleoso and **O. Olatunji,** *Federal Institute of Industrial Research, PMB 21023, Ikeja, Oshodi, Lagos, Nigeria*

A sudden decline in foreign exchange and the desire for self-reliance made the Nigerian government to change its policy of gradual and partial substitution of imported industrial raw materials to one of total and immediate substitution. This policy has affected, among others, the brewery industry, which imports its entire need of barley malt. The need for a local substitute thus became imperative as the ban on import of barley malt became effective from 1 January 1988.

Prior to this decision, various laboratory, pilot plant, and commercial tests were carried out to establish that sorghum malt or grits can be used for brewing. Appropriate malting and brewing procedures for using sorghum were established by the Federal Institute of Industrial Research, Oshodi, using 25,50, and 100% substitution. Beers made with malted sorghum were tested and compared with existing brands made from barley malt. The efforts of the Federal Institute of Industrial Research, the Federal Ministry of Science and Technology, and various brewing houses in complying with the objective of import substitution are discussed.

Traditional Technologies in Small-Grain Processing

S.Z. Mukuru, *International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh 502 324, India*

Traditional small-grain (mainly sorghum and millets) producers in the semi-arid tropical parts of Africa and India have developed simple but effective, appropriate technologies to process their grains. These technologies are variable, depending on the types of grains produced. In general, traditional grain-processing technologies are used for cleaning, dehulling, and grinding their grains into flour. In the southern

highlands of Uganda and neighboring areas, where high-tannin sorghum types with soft endosperm grains are extensively grown, a unique traditional technology was evolved to process high-tannin grains before they are consumed. This technology, which is simple and uses locally available material, involves mixing high-tannin grains with wood-ash slurry, followed by soaking the grains in water overnight. The grains are then germinated for 3 to 4 days, followed by drying the grain in the sun, cleaning, and grinding into flour. This treatment effectively detoxifies the grain and improves its nutritional quality up to the level of low-tannin grains. In this paper, traditional cleaning, dehuUing, and grinding into flour of small grains is reviewed briefly; the traditional technology to process high-tannin sorghum grains is described; and its simplicity and effectiveness in detoxification and nutrition quality improvement are reported and discussed in greater detail. The applicability of the technology to a range of sorghum grains, which vary in physical grain characteristics and polyphenols content, is also discussed.

Traditional Technologies in Small-Grain Processing: Roasting and Malting—The Tanzanian Experience[1]

N.T.A. Bangu, *Chairman, Dept of Food Science and Technology, Sokoine Agricultural University, Box 3006, Morogoro, Tanzania*

A recent survey of sorghum utilization in Tanzania revealed that, in some localities, there exists a traditional practice of roasting sorghum prior to grinding into flour and subsequently using it to prepare soft and / or stiff *Pos*porridges. People practicing the technique assert that it improves the flavor and other edible traits. The practice is, however, uncommon in the country. This paper reports on investigations aimed at assessing the potential of the technique as a means to enhance acceptability of sorghum by a wider sector of the population. The paper goes on to examine research needs to strengthen the recently introduced power flour technique.

Composite Flour, Past, Present, and Future: A Review with Special Emphasis on the Place of Composite Flour in the Semi-Arid Zones

D.A.V. Dendy, *Head, Cereal Technology Section, Overseas Development Natural Resources Institute, Industrial Development Dept, Culham, Abingdon, OX 14 3D A, United Kingdom*

The use of blends of wheat and nonwheat flours, now known as composite flour (CF), was prevalent in earlier times when wheat was scarce. Since the 1960s, much research has been carried out on bread and other products, aimed at incorporating at least a proportion of nonwheat material of local origin and thus limiting imports of wheat.

1. Not presented because author arrived late, but included on the program.

Nigeria is a case where this technology is no longer relevant as the government has banned wheat imports. Opportunities exist for CF where wheat is available locally or can be imported without undue economic strain, and where local cereal flours can be blended into wheat flour for breadmaking.

The technology is available, and CF programs should be part of national policies on sorghum and millets. Opportunities also exist for blending indigenous cereals into products from exotic grains, such as maize.

Sorghum and Maize Pasta and Extruded Products

J.C. Faure, *CIRAD/IRA T Cereal Technology Laboratory, 9 Place Pierre Viala, 34060 Montpellier Cedex, France*

Partial or total replacement of wheat by sorghum or maize flour in baked products has been studied for several years, but only with limited commercial success although the technological problems had been overcome. Much less work has been done on composite pasta and noodles. A review of published results indicates that , without any additive, 30% of sorghum is the maximum rate of incorporation to keep satisfactory cooking qualities and color. Pregelatinization of 25% of sorghum flour, before blending it with the remaining 75%, gave good cooking characteristics, but the color was unacceptable for the consumers. An interesting alternative is the use of heat treatment during drying, keeping the moisture content of pasta at a given value. This treatment proved successful when applied to spaghetti and noodles made from a blend of maize and wheat. At a ratio of 70:30 (maize flour: wheat semolina), cooking qualities were found as good as for 100% wheat products. In addition to appropriate heat treatment, the choice of flour rather that semolina, lipid content below or around 1 %, and low ash content are some characteristics required to obtain more acceptable pasta products for a given rate of incorporation.

Recent Experience on the Milling of Sorghum, Millet, and Maize for Making Nonwheat Bread, Cake, and Sausage in Nigeria

O. Olatunji, O.A. Koleoso, and **A.B. Oniwinde,** *Federal Institute of Industrial Research, PMB 21023, Ikeja, Oshodi, Lagos, Nigeria*

The colossal drain in foreign exchange from wheat import, coupled with reduction in the Nigerian government's foreign exchange earnings, resulted in the banning of whea import in 1987 and the search for local alternatives. Sorghum, millet, and maize were dry milled to different particle sizes of flour and used in making 100% nonwheat bread, cakes, and sausages. The flour of 300 microns gave the best bread, while flour of 150 microns gave the best cakes and sausages. Bread loaves from the 100% nonstarch wheat flour were slightly brittle, and detoxified cassava starch was added to improve its crumb texture. The blend of 70% nonwheat flour—sorghum or millet—with 30% of cassava starch gave bread and confectionary products of better quality. The products from sorghum were more acceptable than those from millet. The peculiar characteristics of the non wheat flour, especially the lack of gluten, necessitate the modification of the present method for using wheat flour. The paper also discusses previous experiences in Nigeria with wheat composites and the beneficial effect of the recent changeover.

The Potential for Extruded Sorghum Food Products in Zimbabwe and for the Regional Market

P. Chigumira, *Willards Foods Limited, P.O. Box 1813, Harare, Zimbabwe*

For many years now, substantial interest has been shown throughout the world in the production of nutritious blended foods as weaning foods, supplements for pregnant and lactating mothers, and for feeding school children or other population groups with high nutritional requirements. Nutritious foods for these purposes can be best made from a mixture of locally grown cereals, locally available protein material, and locally available oilseeds or legumes.

With increase in business pressure, stemming from the Zimbabwe and other countries in the SADCC region find themselves in, most companies are searching for new ways to stimulate their business. In food processing, extrusion cooking provides a great opportunity to create new and exciting products. Extrusion cooking can be utilized in the developing countries to convert indigestible cereals to products that are both digestible and palatable. Besides increasing digestibility, extrusion cooking produces shelf-stable products, which are free from contamination with bacteria and molds. Our analysis showed that power costs with extrusion cooking are approximately ten times less than those with drum drying systems.

Following the acquisition of the Brady Extruder in 1981, Willards Foods Limited developed a range of blended foods, powdered nonalcoholic beverages *(mahewu),* and instant maisoy-sorghum puffed flakes. In the *mahewu* products, sorghum levels were as high as 35% and two products were launched. Four maisoy-sorghum puffed flakes were also developed. In the high protein (20%) ready-to-eat maisoy-sorghum puffed flakes, sorghum levels above 20% gave a product with a gritty texture, unacceptable color and flavor, and limited expansion. The higher the level of sorghum in the extruded mix, the poorer the machine performance. At sorghum levels above 40%, th extruder temperature got too hot, and it had to be attended to and adjusted more often. The rotor or screw was observed to wear out too quickly. The demand for sorghum-based extruder products is low, largely limited by :

- **Price.** The price of sorghum is too high in comparison to, say, maize, although nutritionally there are no major differences.
- **Quality.** Red sorghum has an acceptable color and flavor, above certain levels. Samples of sorghum tested showed a high level of sand particles, which resulted in products with a sandy texture.
- **Cultural.** Products made from sorghum, such as *mahewu,* are generally regarded as lower-class products.

The Use of Sorghum for Food in Brazil

R.E. Schaffert, *Centro Nacional de Pesquisa de Millo e Sorgo/Empresa Brasileira de Pesquisa Agropecuaria (CNPMS/EMBRAPA), Caixa Postal 15L 35700 Sete Lagoas, Minas Gerais, Brazil*

The potential demand for composite flours in Brazil is great because the consumption of wheat is greater than the national production. The low cost of imported wheat after the Second World War contributed to a change in the eating habits of the Brazilian population, substituting many traditional foods for products made with wheat flour. Since 1976 the government has spent approximately one billion US dollars annually on importing and subsidizing the consumption of wheat. EMBRAPA has developed technologies for the preparation and use of several composite flours, including the production and use of a composite sorghum flour. Many products have been made, tested, and accepted in the various regions of Brazil. A composite flour made from sorghum is superior to that of maize for some products, because maize flour alters the color and taste of the end product and sorghum flour does not. The use of composite flours in Brazil is technically viable, but it has been economically unviable because subsidized wheat flour costs less. In 1987 the subsidy of wheat was removed, and this triggered the use of several composite flours. There appears to be a demand for sorghum for human consumption in the semi-arid northeast of Brazil. The national Maize and Sorghum Research Center of EMBRAPA is currently developing new white, vitreous-seeded sorghum cultivars suitable for human consumption.

Processing of Sorghum in Botswana for Foods and Feeds: Problems and Opportunities

N.F. Nicholson, *Managing Director, Foods Botswana (Pty) Ltd, P.O. Box 1131, Serowe, Botswana*

Botswana is a semi-arid subtropical country, with a low and highly variable rainfall. Production of maize and sorghum is insufficient to meet the demands of a growing population. Consumption of sorghum products is declining. There is an increasing trend toward maize and wheat products, which are more refined. This trend appears irreversible unless processing techniques are developed to produce more highly refined products from sorghum.

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

V. Subramanian and **R. Jambunathan,** *International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh 502 324, India*

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 indentification 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-panel evaluations in regions where these grains are consumed. Suggestions for increased utilization, including possible alternative uses, are included.

Quality Criteria for Opaque Beer in Zimbabwe

J.M. Chitsika and **M.W. Mudimbu,** *Chibuku Breweries Division, P.O. Box ST 450, Southerton, Harare,Zimbabwe*

Sorghum and millets form a group of versatile and valuable brewing materials for the opaque beer industry in Zimbabwe. In this paper, we discuss the quality criteria for sorghum and millets along the four main purposes which they serve in brewing. The first is the role they play as alternative starch-based adjuncts. The sorghum varieties currently being grown in Zimbabwe are high in polyphenols, however, which limits the use of sorghum as an adjunct. The second and principal use of sorghum and millets is as sources of malt proteolytic and amylolytic enzymes. We assess malt quality on the following key parameters: moisture, sorghum diastatic units, solubility, extract, free amino-nitrogen, and soluble nitrogen. While large stocks of good quality malting grain are available at major depots of the Grain Marketing Board, the maltster currently has no choice in the quality of grain he receives for malting. This results in variation of malt quality. Recommendations are made on availing good quality grain for malting. Thirdly, sorghum and millet malts are sources of lactobacilli and nutrients required for natural souring (lactic acid fermentation). Last but not least, sorghum and millets give opaque beer desirable characteristics of taste and color.

The Breeder's Role In Sorghum Utilization—A Perspective

D.S. Murty, *Sorghum Breeder, ICRISAT, BP 4881 Ouagadougou, Burkina Faso*

Research advances during the last ten years in sorghum utilization and food quality evaluation are briefly reviewed. Grain quality criteria useful in breeding for traditional processing and food quality are summarized. Selection of a few important plant and grain attributes related to utilization is illustrated. Endosperm texture, i.e., proportion of hard and soft endosperm, can reliably predict the potential use of sorghum grain in products. The need for overall improvement of sorghum grain for much wider domestic and industrial use is brought out. The concepts of breeding for specific end uses and total plant utilization for food, feed, fiber, and fuel are discussed.

An integrated breeding scheme, aimed at improved utilization of sorghum, is presented. Finally, the need for collaborative and cooperative efforts between breeders, chemists, food technologists, engineers, and industrialists is emphasized.

Methods of Processing Sorghum into Livestock Feeds

L.W. Rooney, *Professor, Food Science and Agronomy, Texas A & M University, College Station, TX 77843, USA*

Sorghum without tannins is generally considered to be 95% of the feeding value of yellow dent maize for all livestock species in the USA. Sorghum for swine and poultry rations is usually ground in a hammermill. For poultry, the ration is pelleted and reduced to granules. For beef cattle in feedlots, where 85 to 90% of the ration is grain, sophisticated processes including reconstitution, early harvesting and high-moisture storage, steam flaking, popping, micronizing, and exploding are used to improve the feed efficiency by about 10 to 15% over dry, ground sorghum. Experience has shown that sorghum must be more vigorously processed than maize. It is important that the flakes of sorghum be very thin. This relates to the need to disrupt the peripheral endosperm cells to expose the starch to the digestive fluids.

Sorghum hybrids differ in their response to processing. Some especially waxy and yellow endosperm types process more easily than others. Some feedlots pay a small premium for certain hybrids. In general, a white pericarp and a yellow, waxy endosperm would be best.

Brown sorghums with high tannins have decreased feed efficiency, compared to other sorghums. Animals consume more grain to produce the same weight gains, and so the feed efficiency is decreased. Animals prefer nonbrown grains, but they consume high-tannin sorghum rations readily when they do not have any choice.

Sorghum and Millets as Forage Crops in the Semi-Arid Tropics

J.D. Reed, *International Livestock Centre for Africa, P.O. Box 5689, Addis Ababa, Ethiopia*

Sorghum *(Sorghum bicolor[L]* Moench) and pearl millet *(Pennisetum glacum[L]* R.Br.) are grown primarily as forage crops in the USA and Australia, but in smallholder farming systems in the semi-arid tropics they are multipurpose crops, providing food, feed, construction material, and fuel. Forage millet and sorghum are good silage crops in highly mechanized agricultural systems. Silage making is difficult for the smallholder, and cut-and-carry systems are more appropriate. These systems require cultivars that ratoon. The effects of breeding for increased yields on nutritive value of forage and crop residues need consideration. The proportion of cell wall in forage sorghum and millet is high. Digestibility of the cell wall carbohydrates is limited by lignin and related phenolic compounds. Brown midrib mutants of sorghum have altered lignin composition and greater digestibility of the cell wall. Red phenolic pigments in sorghum are also associated with lower digestibility. The cyanogenic glycoside, dhurrin, in sorghum and alkaloids in millet also lower nutritive value.

Digestibility of Sorghum and Millets in Foods and Feeds: The Effects of Processing

J.D. Axtell, *Department of Agronomy, Purdue University, West Lafayette, IN 47901 USA*

Several years ago, Graham and MacLean reported that the protein digestibility of cooked sorghum is markedly lower than that of other cereals when fed to young children recovering from protein malnutrition . Nitrogen absorption was as low as 46% in these trials, conducted at the Nutrition Institute in Lima, Peru. Several follow-up studies have now been completed, using traditional village-processing techniques prior to the feeding experiments. The data clearly show that fermented breads, such as *kisra* from Sudan, markedly enhance the protein digestibility of sorghum grain. Other traditional village-processing treatments have now been shown to also significantly improve the nutritional value of sorghum. The mechanism responsible for the observed differences between sorghum and other cereals is probably related to the cross-linked kafirin fraction in sorghum. Data are presented to support this hypothesis. Genetic variation for this trait exists among cultivars in the world sorghum collection, suggesting that progress can be achieved through breeding as well as through processing technologies.

Small Grains in Monogastric and Ruminant Feeds: Prospects and Problems

C.D. Amira, *Agrifoods (Pvt) Ltd, P.O. Box 290, Kopje, Harare, Zimbabwe*

Maize grain and its milling byproducts, maize bran and hominy chop, are the main sources of dietary energy for ruminant and monogastric feeds in Zimbabwe. In view of the importance of maize as a major source of food for human consumption, and because only the higher rainfall areas of Zimbabwe are suitable to produce maize, it is clearly desirable to look at alternative sources of energy for livestock feed. Sorghum and millets, better adapted to the lower rainfall areas, offer an alternative to maize for the feeding of livestock. However, very little use of these grains is found in commercial animal feed production due to such factors as: (a) pricing; (b) need for supplementation of poor protein content; and (c) cost of processing. This paper looks at the animal feed industry in Zimbabwe, reviews literature on the use of small grains within the livestock industry, and gives recommendations on the use of products from these grains for the commercial feeding of livestock.

Industrial Uses of Sorghum in Nigeria

J.S.T. Bogunjoko, *Technical Manager, Cadbury Nigeria Limited, Isheri Road, P.O. Box 164, Ikeja, Lagos, Nigeria*

Cadbury Nigeria Limited, Ikeja, has pioneered the industrial use of sorghum in Nigeria, and this paper discusses our experience and the present state of sorghum usage by Nigerian industries. The changing economic prosperity of Nigeria , indicated by the massive devaluation of the Naira over the past 8 years, has meant that the cost to the industry of malted barley has varied from-N300.00(US $ 480) t^{-1} in 1980 to N2800.00 (US $ 620)t^{-1} in 1987, before a ban was introduced on the import of malted barley. Glucose syrup also varied from about-N300.00 (US $ 480) t^{-1} in 1980 to the present post-1988 budget cost of-N3900.00K (US $ 870) t^{-1}. On the other hand, the price of sorghum has varied from -N200.00 (US $ 260) t^{-1} in 1983 to the present cost of -N800.00 (US $ 180) t^{-1}. These price variations, more than anything else, have brought into prominence the industrial use of sorghum by the beer and food industries in Nigeria. Added to this scenario is the fact that, by and large, agricultural production is once again on the increase and there is a question as to what happens to this increased output of grains.

Industrial Utilization of Whole Crop Sorghum for Food and Industry

Lars Hallgren, Finn Rexen, Pernilie B Peterson, and **Lars Munck,**
CarJsberg Research Laboratory, Dept of Biotechnology,
10 Gamle Carlsberg VEJ, DK-2500 Valby, Denmark

The total utilization of the sorghum plant in a balanced production of food, feed, and selected industrial products will be of high importance in the developing countries. The production of fibers from local cereals as a source of cellulose for paper, particle boards, and chemicals for industry is suggested, with a view to reduce the need for import of these components. Experiences with separation and characterization of botanical components of straw from cereal species other than sorghum are outlined, and parallels are drawn to sorghum. The leaves of the plant can be used for livestock feed or as an energy source. Even the polyphenols from high-tannin varieties may be utilized for the production of glue for particle-board production. Low-tannin sorghum grain is an important potential food source and the starch can be utilized as a raw material for the chemical industry. Industrial processes based on the principle of separating the kernel into components, which can be used for feed or fuel, or which have special food properties (for porridges, brewers'grits, flat breads, composite flour, biscuits, etc.), are suggested.

Sweet Sorghum Substrate for Industrial Alcohol

R.E. Schaffert, *Centro Nacional de Pesquisa de Millo e Sorgo/Empresa Brasileira de Pesquisa Agropecuaria (CNPMS/EMBRAPA), Caixa Postal 151, 35700 Sete Lagoas, Minas Gerais, Brazil*

Sweet sorghum may be used as the raw material for biological transformation into ethyl alcohol, utilizing the same infrastructure and equipment as that utilized in transforming sugarcane into alcohol. In tropical conditions, the harvest periods of these two crops complement one another, allowing for a longer period of alcohol production . Cultural management to ensure a constant supply of the raw material for transforming into alcohol depends upon the knowledge of the period of industrial utilization (PIU) for each cultivar used for each planting period. This has led to a definition of a PIU for sweet sorghum. Discussed herein are parameters and limits for developing a PIU for sweet sorghum and managing sweet sorghum for up to several months. The breeding program at CNPMS/EMBRAPA has developed new sweet sorghum cultivars for tropical conditions, utilizing the PIU developed at EMBRAPA , with a 10% increase in alcohol production over the best cultivar previously available. Research priorities are discussed, as is integrated utilization of sweet sorghum for alcohol production and for food or feed and forage. In central Brazil, real alcohol yields greater that 2500 L ha^{-1} have been obtained from biomass yields between 40 and 501 ha^{-1}.

Potential and Practice Relating to Sorghum as a Source of Sugar in Parts of India[1]

A.R. Ghanekar, C. D. Basarkar, and **N. Nimbkar,** *Nimbkar Agricultural Research Institute, P.O. Box 23, Phaltan, Maharashtra 415523, India*

Sweet sorghum could be grown especially in areas where sugarcane processing units are established. This will help extend the running period of sugar factories and small-scale jaggery units, thereby creating additional employment. The major problems with available sweet sorghum cultivars are: low stalk yields, susceptibility to pests, photothermosensitivity, long duration, and poor grain quality. Keeping in view these drawbacks, a breeding program was carried out during the last 10 years, and most of the problems have been reduced to make the crop economical for sugar production in certain areas. The high starch and aconitic acid content posed a major hindrance in processing the crop for sugar production. Regarding the production of jaggery, these problems have been overcome because a suitable technology has been developed at our Institute. The large-scale cultivation of sweet sorghum poses two major obstacles: uneven maturity of the crop, and a short harvesting period because of the perishable nature of the crop. Because of these reasons, the crop is not being utilized for large-scale sugar production. The problem of uneven maturity has been solved to some extent by developing suitable hybrids. The problem of limited harvesting season more or less still remains.

1. Authors could not attend, but paper ncluded on the program.

Participants

Chris D. Amira
Managing Director
AgriFoods (Pvt) Ltd
P.O. Box 290, Kopje, Harare
Zimbabwe

John D. Axtell
Lynn Distinguished Professor
Department of Agronomy
Purdue University
West Lafayette, IN 47907
USA

Nicholas T.A. Bangu[1]
Chairman, Dept of Food Science
and Technology
Sokoine University of Agriculture
Box 3006, Morogoro
Tanzania

J.S.T. Bogunjoko
Technical Manager
Cad bury Nigeria Ltd
P.O. Box 164, Ikeja
Lagos
Nigeria

Alistair Carney
Regional Chemist, National Foods
P.O. Box 269 TA
Harare
Zimbabwe

J.E. Cecil
Overseas Development Natural
Resources Institute
Storage Department
Culham, Abingdon
OX14 3DA
UK

Phillip Chigumira
Technical Director
Willards Food Ltd
Upton Road, Ardbennie
P.O. Box 1813
Harare
Zimbabwe

J.M. Chitsika
Manager, Central Laboratories
Chibuku Breweries (Harare Brewery)
P.O. Box ST 450, Southerton
Harare
Zimbabwe

D.A.V. Dendy
Head, Cereal Technology Section
Overseas Development Natural
Resources Institute
Industrial Development Dept
Culham, Abingdon OX14 3DA
UK

Arthur T. Dibi
Agronomist
ENDA, P.O. Box 3492
Harare
Zimbabwe

Solly Dinat
Business Manager
Rural Industries Innovation Centre
P. Bag 1 1
Kanye
Botswana

Jacques C. Faure
Chief Cereal Technologist
CIRAD/IRAT Laboratoire de
technologie de Cereales
9, Place Pierre Viala
3400, Montpellier Cedex
France

1. Paper not presented due to late arrival, but included on the program.

A.R. Ghanekar[2]
Sorghum Breeder
Nimbkar Agricultural Research Institute
Phaltan, Satara District
Maharashtra 415523
India

M.I. Gomez
Consultant Food Technologist
SADCC/ICRISAT, P.O. Box 776, Bulawayo
Zimbabwe

S.C. Gupta
Principal Millet Breeder
SADCC/ICRISAT, P.O. Box 776, Bulawayo
Zimbabwe

Lars Hallgren
Food Technologist
Carlsberg Research Laboratory
Dept of Biotechnology
10 Gamle Carlsberg VEJ
DK-2500, Valby, Copenhagen
Denmark

A.R. Hawke
Deputy General Manager
Grain Marketing Board
P.O. Box 8014, Causeway, Harare
Zimbabwe

R. Carl Hoseney
Professor, Dept of Grain Science
and Industry
Kansas State University
Manhattan, KS 66506
USA

L.R. House
Executive Director
SADCC/ICRISAT
P.O. Box 776, Bulawayo
Zimbabwe

R. Jambunathan
Principal Biochemist
ICRISAT, Patancheru
Andhra Pradesh 502 324
India

M. Kaumba
Projects Manager
Small Industries Development
Organisation
P.O. Box 35373, Lusaka
Zambia

O.A. Koleoso
Director, Federal Institute
of Industrial Research
PMB 21023, Ikeja, Oshodi, Lag
Nigeria

C.J. Lightfoot
General Manager, Agriculture
Triangle Ltd
P. Bag 801, Triangle
Zimbabwe

L. Majoko
Development Chemist
Chibuku Breweries
P.O. Box ST 450
Southerton, Harare
Zimbabwe

P. Matete
Head, Nutrition Section
Department of Agriculture
Research
P. Bag 829, Maseru
Lesotho

F. Mmopi
Chief Crop Production Officer
Ministry of Agriculture
P. Bag 003, Gaborone
Botswana

2. Unable to attend, but paper included on the program.

D.R. Mohan Raj
Editor, Information Services
ICR IS AT Center, Patancheru
Andhra Pradesh 502 324
India

J. Moncada de la Fuente
President
College of Agricultural Engineering
of Mexico, A.C.
Sindicalismo 92
Mexico 18, DF

Alex Moshe
Team Leader,
SADCC/PFIAU
P.O. Box 4046, Harare
Zimbabwe

Sam C Muchena
Deputy Secretary (Technical)
Ministry of Lands, Agriculture,
and Rural Resettlement
P. Bag 7701, Causeway
Harare
Zimbabwe

M.W. Mudimbu
Brewing Consultant
Chibuku Breweries
P.O. Box ST 450
Southerton, Harare
Zimbabwe

S.Z. Mukuru
Principal Sorghum Breeder
ICRISAT, Patancheru
Andhra Pradesh 502 324
India

D.S. Murty
Sorghum Breeder
ICRISAT BP 4881
Ouagadougou
Burkina Faso

J.N. Mushonga
Sorghum Breeder
Crop Research Institute
Research and Specialist Services
P. Bag 7001, Causeway
Harare
Zimbabwe

Joseph Mwale
Head, Food Technology Research Unit
National Council of Scientific Research
P.O. Box CH 158
Chelston, Lusaka
Zambia

S. Ndoro
Economist, National Farmers
Association of Zimbabwe
21 Berkeley Buildings
P.O. Box 3087, Harare
Zimbabwe

Nigel F. Nicholson
Foods Botswana (Pty) Ltd
P.O. Box 1131,Serowe
Botswana

A.B. Obilana
Principal Sorghum Breeder
SADCC/ICRISAT
P.O. Box 776, Bulawayo
Zimbabwe

O. Olatunji
Head, Division of Food Processing,
Federal Institute of Industrial Research
PMB21023, Ikeja, Oshodi
Lagos
Nigeria

J.D. Reed
Animal Nutritionist
ILCA, P.O. Box 5689
Addis Ababa
Ethiopia

David Rohrbach
Agricultural Economist
SADCC/ICRISAT
P.O. Box 776, Bulawayo
Zimbabwe

Lloyd W. Rooney
Professor, Food Science and Agronomy
Cereal Quality Laboratory
Texas A & M University
College Station, TX 77843
USA

Tungamirai Rukini
Agricultural Engineer
SADCC/PF1AU
P.O. Box 4046, Causeway, Harare
Zimbabwe

A. Rukovo
Senior Agricultural Economist
Ministry of Lands, Agriculture,
and Rural Resettlement
P. Bag 7701, Causeway, Harare
Zimbabwe

F.E. Sauwa
Research Manager
Small Industries Development
Organisation
P.O. Box 2476, Dar es Salam
Tanzania

Robert E. Schaffert
Project Leader
National Maize and Sorghum
Research Center
(Centro Nacional de Pesquisa
de Millo e Sorgo)
CNPMS/EMBRAPA, Caixa
Postal 151,35700
Sete Lagoas, Minas Gerais
Brazil

Ozzie G. Schmidt[3]
Program Officer
Postproduction Systems
IDRC Regional Office for Eastern
and Southern Africa
P.O. Box 62084, Nairobi
Kenya

V. Subramanian
Biochemist, ICRISAT, Patancheru
Andhra Pradesh 502 324
India

E. Temba
Asst Manager (Seeds Project)
ENDA Zimbabwe, P.O. Box 3492
Harare
Zimbabwe

Malcom Vowles
Production and Extension Officer
Commercial Grain Producers
Association
Agricultural House, Moffat Street
P.O. Box 592, Harare
Zimbabwe

C. Wenman
Technical Director, Triangle Ltd
P. Bag 801, Triangle
Zimbabwe

R.B.H. Wills
Dept of Food Science and Technology
University of New South Wales
P.O. Box 1, Kensington, N.S.W. 2203
Australia

Eric N. Witt
Agricultural Development Officer
USAID Mission to Zimbabwe
P.O. Box 3340, Harare
Zimbabwe

3. Unable to attend; paper read by Mr. T. Rukini.

ICRISAT

International Crops Research Institute
for the Semi-Arid Tropics, Patancheru
Andhra Pradesh 502 324, India

SADCC/ICRISAT Sorghum and Millet
Improvement Program
P.O. Box 776, Bulawayo, Zimbabwe

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