Industrial Utilization of Sorghum

International Crops Research Institute for the Semi-Arid Tropics

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Industrial utilization of sorghum: summary proceedings of a Symposium on the Current Status and Potential of Industrial uses of Sorghum in Nigeria, 4-6 Dec 1989, Kano, Nigeria. Patancheru, A.P. 502 324, India: ICRISAT.

Abstract

This publication summarizes the proceedings of a national symposium on the current status and potential of the industrial uses of sorghum in Nigeria, held at Kano from 4 to 6 Dec 1989. The ban on the import of cereal grains and malt into Nigeria is an important factor leading to increased utilization of sorghum. The emerging principal uses of sorghum as an industrial raw material include production of lager beer, confectionery, beverages, weaning foods, and feeds. Analysis of current demand and supply situation of sorghum grain indicates considerable shortage of food grains and competition. Further in the next 10 years there will be a continued deficit of sorghum grains which calls for an increased crop productivity through use of better cultivars and production practices.

Industrial milling methods of sorghum, currently used in Nigeria, were critically reviewed. The progress, problems, and prospects of using sorghum in the baking, brewing, and malting industries were evaluated. The importance of sorghum straw as a crop residue for grazing animals and of sorghum grain as a raw material for the feed industry were emphasized. Physicochemical attributes of sorghum grain and straw desired for different end uses, and which require improvement through breeding, were identified. There are abstracts of 29 papers presented in five sessions: grain economics and milling, composite flour products, malting and brewing, nonalcoholic beverages and weaning foods, and forage and feeds. Summaries of the discussions following each session as well as recommendations are included.

Resume

Reference: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. L'utilisation industrielle du sorgho : comptes rendus dun Colloque sur l'etat actuel et le potentiel des utilisations industrielles de sorgho au Nigeria, 4-6 dec. 1989, Kano, Nigeria. Patancheru, A.P. 502 324, Inde : ICRISAT.

Cette publication presente les comptes rendus d'un colloque national sur l'etat actuel et le potentiel des utilisations industrielles de sorgho au Nigeria, tenu a Kano du 4 au 6 decembre 1989. L' interdiction sur l'importation au Nigeria des grains et du malt est un facteur important qui a entraine l'utilisation accrue du sorgho. A l'heure actuelle, le sorgho devient la principale matiere premiere industrielle dans la production de biere blonde, de biscuits et confiserie, de boissons, d'aliments pour les enfants, et d'aliments de betail. L'analyse de la situation actuelle de demande et de fourniture de graines de sorgho a indique une penurie considerable de graines alimentaires, ainsi qu'une competition entre la consommation humaine et les besoins industriels. D'apres les previsions, il y aurait un deficit continu de graines de sorgho au cours des dix prochaines annees, ce qui necessiterait une amelioration de la productivite des cultures par l'emploi de cultivars et de pratiques de production plus efficaces.

Les methodes industrielles de mouture de sorgho utilisees actuellement au Nigeria sont critiquees. Les progres, les problemes, et les possibilites d'utilisation du sorgho dans l'industrie de confiserie, de brasserie et de maltage sont evalues. L'importance de la pailie de sorgho comme residu de recolte pour les animaux en paturage et des graines de sorgho comme matiere premiere pour l'industrie d'aliments sont soulignees. Sont egalement identifiees, les caracteristiques physico-chimiques des graines et de la paille de sorgho souhaitables pour des utilisations finales diverses et qui doivent etre ameliorees a travers la selection. L'ouvrage contient les resumes de 29 communications presentees en cinq sessions : economic de grains, mouture, produits composites a base de farine, maltage et brasserie, boissons non-alcoolisees et aliments pour les enfants, fourrage et aliments de betail. Finalement, des resumes des discussions suivant chaque session ainsi que les recommandations generates des participants sont aussi inclus.

Industrial Utilization of Sorghum

Summary Proceedings of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria

4-6 Dec 1989

Kano, Nigeria

ICRISAT

International Crops Research Institute for the Semi-Arid Tropics

West African Sorghum Improvement Program (WASIP), Kano Nigeria

IAR

Institute for Agricultural Research, Samara,

Ahmadu Bello University, Zaria, Nigeria

1990

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The International Crops Research Institute for the Semi-Arid Tropics is a nonprofit, scientific, research and training institute receiving support from donors through the Consultative Group on International Agricultural Research. Donors to ICRISAT include governments and agencies of Australia, Belgium, Canada, People's Republic of China, Federal Republic of Germany, Finland, France, India, Italy, Japan, Netherlands, Norway, Sweden, Switzerland, United Kingdom, United States of America, and the following international and private organizations: African Development Bank, Asian Development Bank, Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ), International Board for Plant Genetic Resources, International Development Research Centre, International Fertilizer Development Center, International Fund for Agricultural Development, The European Economic Community, The Opec Fund for International Development, The Rockefeller Foundation, The World Bank, United Nations Development Programme, University of Georgia, and University of Hohenheim. Information and conclusions in this publication do not necessarily reflect the position of the aforementioned governments, agencies, and international and private organizations.

ISBN 92-9066-188-7

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Preface

R.W. Gibbons

Executive Director, ICRISAT Sahelian Center and West African Programs, Niamey, Niger.

The ICRISAT West African Sorghum Improvement Program (WASIP), Kano, Nigeria organized jointly with the Institute for Agricultural Research (IAR), Samaru, Ahmadu Bello University (ABU), Zaria, a national symposium on the "Industrial Utilization of Sorghum" from 4 to 6 December in Kano. In the Semi-Arid Tropics (SAT), where sorghum is used mainly for direct consumption in the form of traditional foods, Nigeria is emerging as a pioneer in the industrial utilization of sorghum. This development is highly encouraging and has far reaching implications on the program objectives of the concerned national and international research institutes and the various government agencies involved in policy decision, development, and promotion of sorghum crop utilization activities. Therefore, it was timely and appropriate for the symposium to have focussed on problems and prospects related to the production of various sorghum products from the farmer to the consumer stage. Twenty-nine research papers were presented at the symposium in the following sessions: Grain Economics and Milling, Composite Flour Products, Malting and Brewing, Nonalcoholic Beverages and Weaning Foods, and Forage and Feeds. Fifty-one delegates representing various disciplines, research institutes, industries, government, private and public agencies participated in the symposium.

This summary proceedings of the symposium includes: addresses given by the dignitaries during the inaugural session, abstracts of 29 papers that contributed to discussions, summaries of discussions that took place after each session, the final recommendations of the symposium and a list of the participants. This volume will, hopefully, be a valuable addition to the literature on sorghum utilization and provide a good reference to the recent developments of industrialization of sorghum products in Nigeria. The recommendations will serve as useful guidelines to those involved in the improvement of sorghum production and utilization in the SAT.

Inaugural Session

Welcome Address

Col. Idris Garba

Military Governor of Kano State, Nigeria.

Members of the Executive Council; Directors-General and Heads of Extra-Ministerial Departments; the Head of the International Crops Research Institute for the Semi-Arid Tropics; the Head of the Institute for Agricultural Research; distinguished participants; ladies and gentlemen:

I am highly delighted and feel honored to address you this morning on the occasion of the Symposium on Industrial Utilization of Sorghum. I am informed that the participants at this important symposium have been drawn from the Nigerian flour millers, breweries, bakeries, biscuit manufacturers, research institutes, university departments, and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Such a gathering of experts would undoubtedly create the ideal forum for discussion of such an issue of national importance.

Although much has been said in the recent past about the situation of our agriculture and its nonsatisfactory position in the national economy, the need for a turn-around as demonstrated by the tremendous effort of this administration could not be overstressed. In the face of competing national priorities from other sectors of the economy, the agricultural sector has continued to receive a fair share of the budgetary allocation. This is due to our resolve and commitment to attain self-sustaining growth in food production and to increase production of agricultural raw materials to meet the growing needs of our agroallied industries.

Throughout this agroecological zone, sorghum is the principal staple food. It is produced and used in many different ways. The ban on import of maize, rice, and wheat into Nigeria as part of the country's Structural Adjustment Programme (SAP), has increased production of these crops in the past few years. However, more and more of these cereal crops, particularly maize and sorghum, are being used as raw materials in our agroallied industries. This has led to a substantial shortfall in the net quantity of grains available for direct human and animal consumption. Research on increased production and utilization of sorghum, as ICRISAT and Institute for Agricultural Research (IAR) are carrying out, is likely therefore, to ameliorate the food shortage situation mentioned earlier. The theme of your symposium is therefore very timely and is a challenge to all participants, in seeking solutions to the various constraints facing increased production and use of sorghum in Nigeria.

For obvious reasons, the Kano State Government has continued to render all possible assistance in the production of maize, sorghum, and millet. You may need to know, however, that we have embarked on a more deliberate plan of reviving and improving the production of groundnuts and cotton through the introduction of rehabilitation programs for the crops. This is in realization of the fact that in Kano State, there are huge investments in oil, cotton, and flour mills. As a result of the decline in agricultural production, these industries, have been forced to either close or operate far below their capacity as the raw materials are not available. This has resulted in a large number of people losing their jobs and the use of scarce foreign exchange to import some of the raw materials at the expense of our farmers. Hence, our action is aimed at saving these industries, ensuring better returns for our farmers and providing job opportunities for our citizens. I am pleased to say that our humble effort is yielding the desired results.

Distinguished guests, ladies and gentlemen, I would like to observe that on the strength of information available to me, if the research activities of ICRISAT in the last two seasons are anything to go by, farmers who chose to grow sorghum will have the potential to increase their production three-fold, as long as they are prepared to accept the varieties and the technique. I am sure that industries that have been growing sorghum, as well as our farmers, will be pleased about this development. May I, therefore, at this juncture, commend the ICRISAT and IAR for this achievement and for organizing this symposium and would like to assure you of the support and cooperation of all state agencies in the realization of your goals. I would like to use the opportunity to appeal to our individual organizations to really support such research organizations by making generous grants in view of the obvious benefits to be derived.

Finally, it is my pleasure to welcome you to our historic city of Kano. I hope you will find time to visit the places of interest in Kano while you are with us.

I wish you happy and successful deliberations.

Thank you.

Welcome Address

Prof. Adamu Nayaya Mohammed

Vice Chancellor, Ahmadu Bello University, Zaria, Nigeria.

His Excellency, Military Governor of Kano Slate; His Royal Highness, Emir of Kano; Honorable Minister of Science and Technology; Executive Director of ICRISAT Sahelian Center, Niamey; Deans and Directors; Representatives of the Industry; Team Leader of the ICRISAT West African Sorghum Improvement Program; distinguished participants; ladies and gentlemen:

First let me join the Military Governor of Kano State in whole heartedly welcoming you to this Symposium. Some of you have been to Ahmadu Bello University, Zaria, and know about our set up while some of you may not have. For the sake of those who are not very familiar with our set up, Ahmadu Bello University is the largest and most advanced of all the Universities in Nigeria in terms of its numerous academic programs. Indeed, Ahmadu Bello University is regarded as the largest single University in Africa, south of the Sahara. Our University has a student population of approximately 21 000 and an academic staff strength of over 2000. Within this institution are various faculties and research institutes, one of which is the Institute for Agricultural Research, the Coorganizer of this Symposium.

The Institute for Agricultural Research (IAR), which is perhaps one of the oldest in the West African subregion, has over the years conducted extensive research on the major cereal crops, especially sorghum, with the following objectives:

- to improve the yields of the local varieties through population improvement.
- to develop new pure line varieties that are high yielding and adaptable to different ecological zones.
- to evolve cultural and management practices for optimum grain yield.

It is well known nationally and internationally, that most of the improved sorghum cultivars being cultivated in Nigeria today for various uses have been developed and released by IAR. The foundation for much of the success in the use of sorghum as a raw material which will form the bulk of the discussion at this symposium was laid by the pioneering work of researchers in the Institute for Agricultural Research, Samaru. During this symposium you will have the opportunity to interact with our scientists especially the breeders and food technologists and be acquainted with our achievements in sorghum improvement, production and utilization. This symposium, which is jointly organized by ICRISAT and IAR, has come at a time when sorghum, in addition to its importance as a major staple food of the people of the savanna, has now acquired a new role as an industrial raw material in the food and beverage industries.

The Symposium will, I believe, enable you to exchange information and experiences on the problems and constraints of using sorghum in our industries, vis-a-vis its use as a staple food. Whatever these problems may be, I hope that through mutual trust and determination, you will collectively arrive at practical solutions which will be beneficial to our sorghum consumers, industries and research institutes such as ICRISAT and IAR.

You will undoubtedly use this forum to seriously discuss sorghum utilization in all its ramifications with the objective of improving the lot of our peasant farmers most of whom depend on this crop for their sustenance. There can be no question that growing more grain for our teaming populations is vital for the sustenance of life. However, given the current economic conditions which have forced us to look inwards to produce raw materials needed for our industries, your task in determining the potentials of sorghum in our environment is formidable.

International organizations and other institutes should continue to collaborate with the Institute for Agricultural Research, Ahmadu Bello University to consolidate the gains made so far. It is the most welcome development that international organizations such as the ICRISAT and the International Institute of Tropical Agriculture, arc now working closely with our Institute for Agricultural Research.

Once again, I welcome you all to this symposium. Please feel free to visit our programs before you go back to your stations.

I wish you fruitful deliberations and safe journey back home.

Objectives of the Symposium

R.W. Gibbons

Executive Director, ICRISAT Sahelian Center and West African Programs, Niamey, Niger.

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), with headquarters in India, is the global center for the improvement of sorghum, pearl millet, groundnut, chickpea and, pigeonpea crops. The ICRISAT West African Sorghum Improvement Program (WASIP), recently established in Kano, is directed from its regional headquarters located at the ICRISAT Sahelian Center, Niamey, Niger. The foremost objective of WASIP is to increase and stabilize the production of sorghum in this region. Improvement of nutritional and food qualities of the sorghum grain, and extension of its use to industry is the second objective. At the moment, WASIP-Kano has a team of scientists comprising a breeder, agronomist, entomologist, and a physiologist working at our farm in Bagauda. We hope to provide in due course of time minimal laboratory facilities to carry out grain quality analyses.

I take this opportunity to immensely thank the Federal Government of Nigeria, the Kano State Government and the Ahmadu Bello University for having given ICRISAT their full support for the establishment of WASIP at Kano.

Considerable research was carried out at the ICRISAT Center during the seventies to improve the lysine content of sorghum grain. Since sorghum is used in the Semi-Arid Tropics mostly to make traditional foods, our focus shifted later on to the consumer quality or the food quality of the grain. A great deal of sorghum food quality research was carried out during the late 1970s and early 1980s at the ICRISAT center in collaboration with scientists in Africa. The sorghum grain quality symposium organized during 1981 reviewed the traditional food products of sorghum, the physical and chemical qualities of the grain, processing techniques, laboratory food quality evaluation techniques, and potential grain quality standards. These efforts enlightened and influenced the sorghum scientists around the world to pay adequate research attention to the food quality of sorghum which had generally been considered as a feed grain in the industrialized world. Last year, the ICRISAT/SADCC Program based at Bulawayo, Zimbabwe, conducted a workshop on the "Uses of Sorghum and Millets: Policy, Practice and Potential", with particular reference to the SADCC region. We consider that the current symposium on "Industrial Utilization of Sorghum" in Nigeria is thus another step forward in the same direction.

Recently, the concept of "total crop utilization" of sorghum has been gaining momentum. For example, the grain can be used to make foods and drinks. The stalk can yield sugar, fuel, and fibre. The sorghum stalk can be used as forage, and grain as livestock feed. The value of grain assumes more importance when it can substitute imported grains like wheat and barley. Perhaps it might be possible for the scientists to breed sorghum cultivars for diverse end uses. Published information on technology indicates a great potential for industrial uses of sorghum. The objectives of this workshop should be to review:

- How much of the technology has been transferred?
- What are the limitations and technological problems encountered in the industry?
- What are the possibilities for genetic improvement of the crop to suit the current needs?
- What is the potential for increased use of sorghum in the industry?

On behalf of ICRISAT, I extend a hearty welcome to all the dignitaries and participants. I hope that the scheduled group discussions will bring out appropriate recommendations to all those concerned with the utilization of the sorghum crop and that we will all be benefited from this symposium.

Opening Address

Prof. E. U. Emovon, FAS

Minister of Science and Technology, Federal Military Government of Nigeria, Lagos, Nigeria.

His Excellency, Military Governor of Kano State; His Royal Highness, Emir of Kano; Vice-Chancellor of Ahmadu Bello University, Zaria; Executive Director of ICRISAT Sahelian Center, Niamey; Directors of IAR, AERLS, and NAPRI - Zaria; other Directors and Deans of Ahmadu Bello University; Team Leaders of the ICRISAT West African Sorghum Improvement Program and the IITA Cowpea Program, Kano; Distinguished participants; ladies and gentlemen:

I would like to join the representative of the Military Governor of Kano State in welcoming everyone to this symposium which is jointly organized by the Institute for Agricultural Research (IAR), Zaria, and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). I am happy at this development of collaboration between IAR and ICRISAT. We live in a world in which there is always a close interaction between people, and the problems of one group impinge on those of the other. Consequently we must share information to solve our problems. ICRISAT is an international organization and so has ideas and experiences to share with our national research system. I hope that this collaboration will be sustained.

The need to assess the status and potentials of sorghum for industrial and food use cannot be overemphasized. As the major food grain used by most of the inhabitants of the savanna region in Nigeria, and indeed that of the West African subregion, the need to specifically focus attention on the status of sorghum research and utilization is timely. This is very relevant to Nigeria's Structural Adjustment Programme (SAP) which places emphasis on self-reliance and self- sufficiency. A symposium of this nature enables us to work towards attaining self-reliance and security in food.

It is hardly necessary to stress the fact that concerned research on sorghum varietal development and sorghum production packages has had impressive achievements. For example, as many as 17 improved sorghum cultivars have been developed and released for production in Nigeria, covering four ecological zones. In addition, four sorghum types suitable for malting/brewing have been identified and one of which was released over 10 years ago to farmers. It has been under wide cultivation for use in the industrial sector. Several hybrid sorghum varieties have also been bred for high grain yields and are expected to be released soon. Suitable crop management practices including stem borer and other insect pest control, rates of fertilizer application, and postharvest techniques were developed.

It is pertinent to mention at this point the impressive achievements of the Food Science and Technology Research Programme of the IAR, Samaru, and the Federal Institute of Industrial Research, Oshodi (FIIRO) in Nigeria's research effort on sorghum utilization.

Specifically, it is on record that the IAR developed the technology for composite bread using sorghum or maize flour mixed with wheat flour. Indeed, the technology for 40:60 sorghum-wheat composite bread has already been released for adoption by the industrial sector. I am informed that the proportion of sorghum in the composite flour has not gone much higher under laboratory conditions and it is my hope that in the next few years it should be possible to reduce the proportion of wheat in composite flour mixes. I must mention here that composite flour of maize and cassava has also been developed by FIIRO. Independently the Lever Brothers Ltd., developed similar composite flour and now market a cake mix of this composite. As regards the brewing industry, the combined effort of the IAR (which developed the sorghum variety SK-5912), FIIRO and Project Development Institute has resulted in the successful development of the technology for malting of SK 5912 variety. Alcoholic and nonalcoholic beverages, as well as confectionary products from sorghum have long been on the store shelves. These and similar achievements are, indeed, a credit to the national research system.

This is not to say sorghum production and utilization in Nigeria is not without problems and shortcomings. Indeed, it is precisely because of the gaps in the information about sorghum that prompted the Federal Military Government of Nigeria to accept the request of ICRISAT to establish the West African Sorghum Improvement Program in Nigeria based in Kano to foster collaboration with the IAR, Samaru. To fill these gaps research in the following areas is important:

1. The development of suitable varieties that are considerably high-yielding than those currently in cultivation for both human and industrial use: In this regard, there is no doubt that the quickest way to attain this goal would be related to the development of sorghum hybrids. However, I must caution that ICRISAT's involvement in research on hybrid sorghum versus pure line must take into account the level of technology available in the country at the farmers' level, as well as the socioeconomic indices for the effective sustenance of any improved technology. Drawing from our experience so far with hybrid maize development, and particularly the state of the seed industry, and problems of inputs, I believe that as of today, effort and resources devoted to hybrid sorghum research vis-a-vis the development of pureline sorghum varieties are in proportion of 20:80. This is not satisfactory, and we should therefore increase it to 40:60, as the infrastructural support and technology improve to support hybrid sorghum culture.
2. The involvement of ICRISAT in the development of early maturing sorghum varieties which are suited for the relatively dry areas of Nigeria and where agriculture is entirely based on grain economy. Indeed, the very core function of ICRISAT and the location of the ICRISAT-WASIP make this involvement and expectation natural.
3. The involvement of ICRISAT in *Striga* sp research: There is need to emphasize the importance of this weed in the economy of the entire savanna region. Virtually every important crop in the region is threatened of destruction. These include sorghum, maize, cowpea, and several other annual crops. I have high expectations that, both ICRISAT and other international agricultural research institutes, particularly International Institute of Tropical Agriculture (IITA), will work together to provide methods for the eradication/control of *Striga* sp through research. I am sure that if *Striga* sp is eradicated, the yields of cereals will increase and food production will be improved.

While expressing any expectations in respect of the ICRISAT, I strongly hope that all activities relating to sorghum research by ICRISAT would be in close cooperation and collaboration with IAR, Samaru. Such cooperation will ensure relevance of its activities to Nigeria's needs. Some of the problems that have affected meaningful collaboration between International Agricultural Research Centers and National Agricultural Research Centers, include poor acknowledgment of the roles and contribution of the scientists of one party in the achievements of the other. It will not be ethical to ignore any contribution by a collaborator. I will strongly advise that IAR and ICRISAT should be mindful of this important fact in order to sustain a healthy relationship as is evidenced in today's joint symposium.

Finally, through the Executive Director of the ICRISAT Sahelian Center I would like to thank the Director General of ICRISAT for his support that has made this symposium possible. Indeed, I would like to put on record my appreciation for the contribution of ICRISAT towards the completion of the IAR office and laboratory block at Kadawa. This action of the organization has gone a long way to assure the viability of this project. The continued close collaboration between the IAR and ICRISAT-WASIP on the one hand and the Lake Chad Research Institute and the ICRISAT-Sahelian Center on the other, is well recognized and appreciated by the Government of Nigeria. Hope that the understanding with respect to this project will be sustained and thus contribute to our food security.

Once again, I welcome all participants to this symposium and wish you fruitful deliberations. I also look forward to your recommendations.

Thank you.

Grain Economics and Milling

The Nigerian Grain Market and Industrial Utilization of Sorghum: A Perspective

G.B. Ayoola and F.S. Idachaba

University of Agriculture, Makurdi, Nigeria.

An economic perspective of the cereal grain market and the increasing industrial utilization of sorghum in Nigeria was presented. The demand and supply sides of the grain market were explored. The main intervention instruments in the market were surveyed. Finally, the implication of these factors in industrial utilization of sorghum were discussed. It was concluded that, the demand and supply of the grain market have important implications for increasing the industrial utilization. In particular, sorghum which is traditionally a nontraded commodity, requires successful programs in backward integration and productivity improvements. The existence of substitutability among grains also offers the advantage of diversified input base to the industries. Finally, the present policy of nonintervention in the grain market demands high production efficiency in the use of sorghum as an industrial raw material.

Industrial Utilization of Sorghum in Nigeria

A.O. Aribisala

Raw Materials Research and Development Council (RMRDC), PMB 12873, Lagos, Nigeria.

Till recent times, sorghum has been the principal staple food in Nigeria. The Structural Adjustment Programme (SAP) of the Nigerian Government made it imperative for the food and beverage industries to explore options of finding local sources of their raw materials. This has become an important factor in enhancing the utilization of sorghum. The emerging principal uses of sorghum as an industrial raw material includes production of biscuits and confectionery, beverages, weaning foods, and beer.

Grits, flour, and meals from sorghum are now common items in the market. Soft biscuits and cookies are being made using sorghum, maize and wheat composites, while cakes, and nonwheat breads have become a subject of increasing scientific and technological enquiry, producing encouraging results. In the infant weaning food sector, in spite of unlimited potential, progress has been slow, as the installed capacity for industrial malting is limited. Sorghum currently has the greatest potential of being used as a raw material in the brewery subsector. Many brands of beer in the market have substantial content of local sorghum and maize. This has led to a possible proliferation of small-or medium-scale malt industries.

The current estimated demand for sorghum in Nigeria is about 4 million t a^{-1} while the projected potential demand through the year 2000 is estimated to be about 8 million t a^{-1}. This deficit situation is likely to worsen if the anticipated potential industrial uses are realized in the near future. The Raw Materials Research and Development Council (RMRDC) study of 1989 concluded that the potential for the utilization of sorghum brewing technology may not be realized in view of the general acute shortage of food crops in the country because of low productivity and high demand pressures for human consumption and industrial needs. There is an urgent need for increased productivity in the agricultural sector. One remedial option among others is increased research and development effort towards solving the identified production problems of sorghum. More than before, it is now imperative that potential for industrial uses has a direct bearing on the future choice of research themes.

Sorghum Milling in Nigeria: A Review of Industrial Practice, Research, and Innovations

P.O. Ngoddy

Department of Food Science and Technology, University of Nigeria, Nsukka, Nigeria.

Traditional and industrial milling of sorghum in Nigeria was reviewed with a focus on the impact which the ban on wheat import has had on the technological progress. Traditionally sorghum was dehulled in the households by the mortar and pestle method followed by grinding in a stone mill. With the advent of small power driven plate mills, the bulk of the sorghum was custom-milled to whole flour while several customers still brought traditionally dehulled grain to the mill for reduction into fine flour. During the early 1980s two installations of industrial scale were established in Nigeria using an abrasive pearling principle and a hammer mill for grinding the pearled sorghum. The ban on wheat imports initiated rapid changes in sorghum milling technology in Nigeria. Most of the 22 large wheat milling installations of the country which used Buhler Miag® or Henry Simons® equipment have been modified and retooled at a very high cost to suit maize and sorghum milling. However, these mills are operating at 10% of their installed capacity and are still facing production, quality, and marketing problems. After the ban on wheat imports, about 15 to 20 new medium scale milling plants with horizontal dehulling devices were also installed. These mills were designed to be versatile and flexible to mill a range of grains such as sorghum, maize, and legumes. In spite of rather low extraction rates, these mills have been successful and could respond to the needs of brewers, biscuit manufacturers, and other industries. Import costs of these medium scale milling plants are highly prohibitive. Considering the cost and the large number of individual installations that will be required to satisfy Nigeria's expanding demand for cereal flours and allied products, it is recommended that efficient indigenously

manufactured sorghum milling machines (0.25 to 1 t ha^{-1} capacity), low cost and high local content are encouraged. Nationwide surveys indicated the availability of such indigenously fabricated equipment and machinery.

Dry Milling of Sorghum

W.A. Obiana

Northern Nigeria Flour Mills Ltd., Bompai, Kano, Nigeria.

The Northern Nigeria Flour Mills Ltd., which was originally designed to mill wheat, has been processing sorghum with appropriate modification of the existing facilities and addition of a decomatic decorticator. Grains from a range of locally grown sorghum cultivars including yellow *kaura* and white *farafara* were processed and each of them exhibited individual processing characteristics. Dry milling of sorghum involved three operations: cleaning, decortication,and grinding. In the cleaning section, impurities like foreign matter, stones, sand, metallic objects, and light impurities are eliminated. The decomatic decorticator is a vertical machine with a capacity of pearling 1.5 t ha^{-1} of grain and is equipped with six rotor mounted carborundum discs and a screen mantle. The decortication principle is abrasion and the extent of decortication can be adjusted. It was found that 20% decortication could be optimum. Tempering of grain prior to decortication decreased throughput, and increased the amount of broken grains, ash, and fat contents of the products.

At the Northern Nigeria Flour Mills, a combination of a roller stand with two passages and a hammer mill were adopted for grinding pearled sorghum. This grinding system can produce either brewers grits or flour, or both if need be. Northern Nigeria Rom-Mills is marketing pearled grains as shinkawa® which can be used to make products similar to boiled rice products. It was suggested that researchers should develop cultivars of high yield and good mechanical processing qualities. Facilities for chemical analysis of grain and flour products are required by the millers to practice quality controls.

Sorghum Milling Techniques

R.D. Mathur

Inter-State Hour Mills Ltd. Yola, Nigeria.

Sorghum is a staple food in Nigeria. Recently the breweries started using sorghum grits because of the nonavailability of barley malt. The United Nations Development Programme (UNDP) and Food and Agriculture Organization (FAO) have introduced sorghum milling systems into Senegal and Sudan. Small dehulling cum grinding machines are also in use in Botswana for dry milling of sorghum. In Nigeria, there are very few milling plants exclusively meant for sorghum. However, some wheat flour mills are being used for milling sorghum with modification in flowsheet. In the near future, more plants for milling sorghum are expected to be in operation.

A sorghum milling plant using the modified wheat system consists of facilities for cleaning, tempering, dehulling, degermination, and milling. Grains are thoroughly cleaned before processing. The machines used in the cleaning section include separator, magnetic separator, and dry stonner. The tempering or laundry section consists of a dampening unit with automatic controls for regulating the flow of water and resting time. Tempering allows water to penetrate the hull layer and facilitates dehulling and degermination. The dehulling section consists of a number of decorticators and the product is recovered through the screen. The milling section consists of roller mills, purifiers, plan sifters, and a centrifugal sifter. The roller mills are identified as first, second and third break, where fluted rolls are used; and for reduction of grits into flour, polished smooth rolls are used. The dehulled whole seeds are conveyed to the first grinding fluted rolls known as first break. The dehulling rate is adjusted as desired. The product which passes through the screen (usually small broken seeds free from germ) is conveyed to second break roll. The flour obtained from the break system is high in fat content, but of acceptable color. Flour or grits can be produced as required. The germ and hulls recovered could be used as animal feed.

Sorghum Milling at Zaki Flour Mills

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The Zaki Flour Mills was commissioned in Sep 1987. The project is a joint venture of the Federal Government of Nigeria, State Government of Bauchi and the technical partners, Messers Komplex of Hungary. Cereal grains like wheat, maize, sorghum, and millet were processed. Sorghum was processed into flour of 200 μ to 300 μ particle grade and grits of 300 μ-1100 μ particle grade through dry milling system. Flour of 200 μ particle grade is used mainly by the biscuit manufacturers while the 300 μ particle grade flour is used for traditional consumption in the form of *tuwo.* The grits are used mainly as adjunct by the brewing industry. Among various sorghum cultivars processed, yellow colored *kaura* grains were found to be the most suitable for milling with an average extraction rate of 82%. Quality control tests (moisture content, impurities, hectolitre weight, 1000 seed mass, immature grains and insect count) were carried out on the raw material. Extraction rate, particle size analysis, estimation of sand particles and ash determination tests were done on finished products. Rodent and insect control during grain storage was a problem. Agricultural scientists should identify drought-resistant sorghum varieties which can give high flour yield. Extension workers should advise farmers on appropriate crop husbandry, harvesting and storage methods to ensure good quality raw materials devoid of insect infestation.

Summary of Discussions

Several comments were made on the lack of appropriate analytical facilities within the milling industry for quality control of grain and flour products. It was regretted that millers were investing huge amounts of foreign exchange only on the machinery without due attention to quality control laboratories. Some research institutes also lack these facilities. It was recognized that, quality analyses have become the burden of universities upon request from millers. It was suggested that universities should be supported with centralized and well equipped laboratories, and that research institutes and industries could get their samples analyzed against payment.

Further discussion focussed on the milling techniques in use. It was felt that roller milling of sorghum on machinery intended for wheat might not be effective. However, it was recognized that, irrespective of the milling system used, hard endosperm grains are suited for higher extraction rates and better quality products. There were questions on the value of tempering the grains before dehulling, which resulted in increased broken grains, fat, and ash contents. It was clarified that tempering affected the storage quality of flour for industrial purposes although it might not affect domestic consumers who do not store the product for a long time. Dry milling was found to be more suitable for producing brewer grits.

There was a serious concern about the lack of spare parts, particularly for small machines. There is also shortage of steel for fabricating sheets and other parts for the machines. It was agreed that efforts should be made to study the supply and demand for spare parts so that government can take appropriate steps to encourage local manufacturers to produce a range of spare parts. Research and Development personnel should look into novel and indigenous systems rather than focussing their efforts on a few old milling systems.

Some discussants stressed the importance of monitoring the effect of a range of pesticides which are under intensive use to protect grain during storage. Residual toxic effects might have dangerous consequences on the consumers.

It was observed that excessive government intervention might disturb the supply and demand forces of the grain market Questions were raised about the feasibility of backward integration, which involved huge capital investment by the industries in the agriculture sector. It was clarified that huge investments could be avoided by following the contract grower method.

Composite Flour Products

Sorghum as a Raw Material in the Baking Industry

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The baking quality of wheat and sorghum composite flour and the nutritional quality of the resultant bread were determined. The specific loaf volume of the bread decreased with increased substitution of wheat. Organoleptic tests of the composite bread showed that 70% of the taste panelists rated the overall quality of 70 wheat: 30 sorghum composite bread as good. Proximate composition of the composite bread showed that it contained much lower protein, and higher crude fiber contents than 100% wheat bread. The shelf life of composite bread at room temperature was lower than that of 100% wheat bread. It was found that addition of 2-4% pentosans to composite flour (up to 50% substitution level) improved the quality of the bread. Prefermentation of the sorghum flour up to 20 h was found to have positive effects on the baking quality of the wheat and sorghum composite flour. Good quality snacks were produced from wheat: sorghum composite flour up to the level of 60% substitution. Further increases of wheat substitution in the composite flour produced poor quality snacks.

Use of Sorghum as Composite Flour in Baking

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Blends of wheat, sorghum, and soybean flours in the proportion of 65:30:5 was used to make bread, and 40:55:5 to make biscuits. Replacement of wheat up to a level of 20% with sorghum flour produced acceptable bread, while further substitution up to 55% sorghum flour could give acceptable biscuits. It was also found that a blend of 70% sorghum flour and 30% detoxified cassava starch could produce acceptable bread and cakes.

Bread from Composite Flours

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Among cereals, sorghum was found to be the best substitute for wheat in composite flours. A wheat and sorghum proportion of 70:30 was found to be the best. Sugar, yeast, butter, salt, water, and preservative are added to the composite flour in appropriate quantities and all the ingredients are mixed at a high speed in a machine for 15 to 20 min. The dough is allowed to ferment in the mixer until it almost doubles its initial volume. This is followed by knocking back the dough in the mixer, scaling, and moulding. The moulded dough is put in the baking pan and allowed to pufff to maximum volume. Baking follows at temperatures ranging from 230℃ to 250℃. The loaves are allowed to cool after baking. Experience showed that composite flour required additional quantities of sugar, yeast, and water than 100% wheat, to make the bread tasty. Baking of composite dough required higher temperatures. The shelf life of composite bread is relatively less than 100% wheat bread in spite of the use of preservatives. The texture of composite bread was less acceptable. One of the major problems facing bakers is the smaller volume of composite bread as compared to 100% wheat bread from similar quantities of composite flours and wheat flours. It is apparent that, to produce a unit volume of bread, a relatively higher quantity of composite flour is necessary. It was suggested that government should subsidise the cost of farm inputs and ensure increased production of local cereals.

Current Status of Composite Flour Technology and Prospects with Particular Reference to the Production of Biscuits in Nigeria

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The import of wheat was banned, and therefore, the option of substituting wheat flour with other cereal flours was explored. Sorghum and wheat composite flour (50:50) was used to make biscuits by the "moulding" method. Suitable modifications were made in creaming, mixing, and baking techniques. In spite of good results achieved, several problems are associated with the industry. Although the cost of flour decreased by the substitution of wheat with sorghum, prices of other items such as fat increased by

200%, and sugar by 400% during the last 2 years. There might be a scarcity of sorghum flour in the near future. Breakage of sorghum composite flour biscuits in process and handling is a serious problem. Influx of wheat biscuits into the country is a disadvantage. It was suggested that readymade composite flour mix could be supplied by the millers. Collaborative efforts are required between researchers and industry to investigate problems at the pilot-scale production stage. It was proved that sorghum and wheat composite flour is a viable alternative to 100% wheat flour biscuit production, provided that in future there will be adequate supply of wheat flour.

Use of Sorghum Flour in Biscuit and Wafer Production: The Nasco Experience

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The ban on import of wheat into Nigeria prompted Nasco Foods to experiment on substitution of wheat with local cereals like maize and sorghum in biscuit production. Initial attempts to substitute wheat with maize were not successful as the dough lacked binding strength. The experience was similar with tuber flours which posed an additional problem of bitter taste to the biscuits. However, cooked maize grits could provide a pregelatinized flour which gave adequate binding strength to the composite flour. Production trials in later stages had glucose, milk powder, emulsifiers, lecithin, and other ingredients included in the recipe. It was possible to produce biscuits of acceptable quality using 50:50 wheat and sorghum composite flour. Short dough biscuits could be prepared by using 15% of total flour from cooked maize and 85% of wheat and sorghum composite flour. Wafer production required little quantities of pregelatinized maize flour. In general, biscuits from composite flour were darker in color than wheat biscuits, and addition of artificial colors and flavors was necessary. Texture of composite flour biscuits was denser while palatability and shelf life were poorer than that of wheat biscuits. The coarser particle size of sorghum flour relative to wheat flour resulted in some of the adverse effects. Breakage of composite flour biscuits in production and packing was higher than that of wheat biscuits. Substitution of wheat flour up to 25% with sorghum flour in production of short and hard dough biscuits and wafers was cost effective without affecting quality, breakages, and plant efficiency. It was suggested that improved milling techniques to produce sorghum flour with particle size comparable to that of wheat flour can increase the possibility of higher substitution.

Processing and Acceptability Studies of Soy-enriched Nonwheat Biscuits

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This study compared the dough characteristics of corn-soy, sorghum-soy and rice-soy (each at 20, 25, and 30% soy inclusion), flour blends and the taste panel acceptability of biscuits produced with these combinations.

Peak viscosity of the flour blends decreased as the level of soy increased. Sorghum-soy flour blends recorded the highest peak viscosities compared to other blends. Each flour blend showed a decline in its cooking properties, as the level of soy was increased from 20 to 30%.

The sorghum-soy flour blend recorded the least moisture content while the corn-soy flour blend had the highest protein and phosphorus contents.

The spread factors of biscuits prepared from the flour blends increased directly with their respective viscosity. Sorghum-soy and rice-soy flour blends gave higher spread factors than the other blends irrespective of the level of soy inclusion. While the biscuits from sorghum-soy blends were brown in color with a slight spread (4.82-5.54), biscuits from rice-soy blends were golden brown. Biscuits from corn-soy flours generally took about 25% less baking time compared to others and exhibited little spread.

In general, overall acceptability of all the biscuits decreased with increased level of soy in the flour blend.

Summary of Discussions

There was an extended discussion on the quantity and quality of locally grown wheat available for composite flour production. The quality of flour from locally grown wheat was found to be suitable for biscuit production. However, the bakers found local wheat flour to be relatively less suitable for bread making than imported wheat flour. Doubts were expressed whether the farmers were growing recommended wheat varieties. It was strongly felt that the Government should take appropriate steps to boost local production of wheat, and avoid competition of local wheat flour or composite flour with smuggled or imported wheat flour.

Regarding profits from composite bread sale, it was clarified that since the quantity of composite flour necessary to produce a unit volume of bread relative to 100% wheat bread is higher, profits could be slightly lower. The relatively lower protein content of composite bread than that of 100% wheat bread has no bearing on its price because prices of sorghum and wheat do not depend on their respective protein contents.

Considerable interest was expressed in the use of pentosans to improve composite bread quality. It was pointed out that rye pentosans were used for experimentation and unless pentosans extracted from local raw materials or sources are available, the method may not be economical. Similar comments were also made with respect to chemical agents like mycoban, used for improving shelf life of the bread. Further studies are required to know the extent of prefermented or malted sorghum flour to be mixed with composite flour for producing bread of optimal quality. Cassava starch was found to be more suitable than cassava flour in producing composite breads.

It was suggested that Nigerian consumers should consider favorably a Nigerian bread or product rather than "European" quality bread. In future, novel products of sorghum and other local cereals, acceptable to Nigerian culture and traditions should receive more attention from researchers.

Malting and Brewing

Utilization of Sorghum in Brewing Lager Beer in Nigeria

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Following the ban on the import of barley malt in 1988, the brewing industry in Nigeria has been utilizing sorghum and maize as raw material for lager beer production. Sorghum can be used as raw grains, grits or malted material. The bulk of the sorghum grain currently used by the brewers in Nigeria is from the varieties, SK 5912 and *farqfara.* The malting processes in use are still empirical. In contrast to barley, sorghum malt has low levels of ß-amylase, ß-1,3,1,4-glucanase, and ß-D-glucans. During the mashing operations, external heat stable enzymes, namely, ∝-amylase, neutral protease, ß-glucanase, cellulase and amyloglucosidase are required. Although the process of sorghum brewing is still empirical, results so far obtained in various breweries appear encouraging. However, research is needed to resolve several problems. Selection and breeding of suitable sorghum cultivars with high extract yield and soluble proteins, low polyphenol, and fat content, coupled with high yield is required. Development of improved malting techniques and brewing processes and their adaptation are needed.

Problems Associated with the Use of Sorghum for Lager Beer Production

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Lager beer can be produced from barley malt and any cereal adjunct including sorghum. However, the production of lager beer from 100% sorghum is entirely a new concept originating from Nigeria and has been the center of controversy among brewers the world over in recent times. It is now possible to brew some sort of beer from 100% sorghum using exogenous enzymes but several problems are being encountered on the process line. These problems relate to equipment, sorghum malting, mash gelatinization, saccharification, lautering, wort fermentability, body fullness, and acceptability of the final product by the consumers. It was concluded that solution to these problems lies in the development of sorghum cultivars that have low gelatinization temperature, low polyphenols, low lipid, high diastatic power,and readily solubilized protein.

Sorghum in Lager Beer Production: Progress and Prospects

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The Nigerian brewing industry started with the establishment of a brewery in 1949. Currently, there are 33 brewing plants in Nigeria with a theoretical total production capacity of 19.61 million hL a^{-1}. In order to prevent the fast decline of foreign reserves, the Government of Nigeria adopted several regulatory measures to stem the outflow of funds from the country, under the Structural Adjustment Programme (SAP). With the ban on the import of barley malt, the brewing industry became totally dependent on locally produced cereal grains, which has also started to grow, leading to its entry into the agriculture sector. Given the fact that malting losses are relatively higher in sorghum than in barley and the rudimentary status of local malting technology, higher cost of lager beer production may be unavoidable in the short term.

Selection of sorghum cultivars with desirable malting qualities should be possible with the aid of classical plant breeding techniques, and also, the recent advances in biotechnology. An understanding of the nature and properties of sorghum amylases may be vital for the development of Nigerian brewing industry. Basic studies on the physiology and biochemistry of sorghum malting and the process of yeast fermentation should continue. A substitute for the bitter principle of beer, derived from hops, could be possible with the use of flavonoid compounds from local sources. The problem of haze formation in beer still needs to be resolved. Local production of synthetic enzymes should be encouraged. The establishment of a brewing research foundation in Nigeria is recommended. Provided the government policies are stable, the future of the Nigerian brewing industry will be brighter in the next 20 years than it has been in the last 20 years.

Brewhouse Performance of Sorghum Grain and Malt: Problems and Prospects

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Brewhouse performance of raw materials such as barley and sorghum is affected by various factors. Sorghum grain lots available in the Nigerian markets are highly variable and contain seeds of nonuniform size, impurities, and debris which pose peculiar milling problems. Nonuniform grain lots lead to brews of different organoleptic qualities. The qualities of sorghum malt supplied by different malting plants also vary. The milling procedures like setting of rollers for crushing barley malt and sorghum malt are not the same. In the mash tun, relatively higher temperatures, and longer time are required for gelatinization of sorghum starch. The behavior of sorghum mash during filtering differs from that of barley, particularly when 75% or more of barley malt is replaced with sorghum. It was concluded that brewhouse performance of sorghum can be improved by appropriate choice of grain lots by screening, better milling procedures, and improved mashing techniques in combination with good exogenous enzymes.

Brewing of Clear Beer from Sorghum Grains of SK 5912 Variety without Addition of External Enzymes to Achieve Saccharification: A Case Study

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The qualities of products obtained by malting and brewing grains of SK 5912 variety on an industrial scale without addition of synthetic enzymes for complete saccharification, and according to a patented method were reported. Floor malting was done at Agro Allied Industry, Ilesha, Nigeria, and brewing operations were carried out at International Breweries Ltd., Ilesha, Nigeria by a special patented method developed by Worldwide Brewers and Malt Ltd. of Ibadan, Nigeria. Properties of sorghum malt were in general poor compared to barley malt, but total soluble sugars and cold water (%) extract of the sorghum malt were relatively higher than those of barley malt. The qualities of sorghum wort compared favorably with those of commercial barley wort. However, the sorghum malt mashing process required longer time when compared with barley wort. The physicochemical properties of sorghum beer obtained from 100% sorghum malt were all within acceptable limits of commercial lager beer while organoleptic properties were acceptable to the tasters.

Industrial Production of Sorghum Malt in Nigeria

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Industrial malting is a recent enterprise in Nigeria. It has been estimated that the Nigerian brewing industry requires 4 50 000 t malt a^{-1}. Savannah Grains and Food Processing Co. Ltd. (SGFPC) is one of the three enterprises in Nigeria, currently producing sorghum malt on an industrial scale. Use of malted sorghum, rather than raw grains, as a source of fermentable sugars, was found to be advantageous. During malting, the sorghum grains are cleaned, washed, and steeped in water for 24-48 h. Appropriate chemicals are added during the steeping process to prevent the growth of molds. At the end of steeping, the grains are further washed. The moisture content of the grain should be between 40-46% at the time of transfer to an aseptically clean floor (100 x 40m). The grains are heaped to a thickness of 152-221 mm and left to germinate for 3-5 days with frequent aeration. Temperature is maintained at 25-30℃ and relative humidity at 85-95%. The resulting malt is dried to a moisture level of 8-10% in a rotary drier at 75℃. The dried malt is mechanically agitated and the sprouts are removed by screening. SGFPC has succeeded in automating this malting process and this process can produce 10 000 t malt a^{-1}. Grains of sorghum varieties SK 5912, Farafara, and HQSV are currently being used for malting. HQSV was found to be superior to other varieties for malting purposes.

Desirable properties of sorghum grain required for malting include: low gelatinization temperature of starch, soft endosperm, loosely packed starch granules, and easily accessible protein bodies associated with starch, high amylase activity, low polyphenol and tannin content, high protease and b-glucanase activities, and a low rate of cyanogenesis. The byproduct of malting, namely sprouts (dried shoots and roots), currently being used as organic fertilizer can be a rich source of dhurrin. Problems encountered during industrial malting include: molds, cyanogenesis, heavy malting losses, insufficient modification, and nonuniform germination. Indigenous production of synthetic enzymes should be encouraged. Demand for sorghum malt for manufacture of beers, syrups, beverages, microbiological media, and baby foods will increase in the next 10 years.

Summary of Discussion

The discussion brought out the fact that currently sorghum and maize are the principal cereals in use by the brewers in Nigeria. Some brewers preferred the use of sorghum grain or grits rather than malt because of problems related to wort quality. However, it was pointed out that the resistance from some brewers against the use of sorghum malt was based on hopes of a probable change in government policies. It was clarified that 100% sorghum beer is acceptable to Nigerian consumers and can compete in the market with other brands. The Nigerian brewing industry did a commendable job in quickly reorienting its technology towards local raw materials after the ban on barley malt Some of the brewers are investing in farms to cultivate maize and sorghum.

The question of malting losses in sorghum received considerable attention. Relatively higher malting losses of sorghum (16-22%) than that of barley were attributed to the naked nature of sorghum grain in contrast to barley grains with husk. It was suggested that methods of calculating real malting losses should be accordingly modified or adjusted. It was also claimed that malting barley required higher energy and longer time than with malting sorghum. Methods of estimation of enzyme activity in sorghum malt were also questioned. Different brewers are adopting different methods and units of enzyme activity, recommended exclusively for barley malt. It was suggested that Novellie's KDU method might be more suitable for sorghum malt analyses.

It was claimed that complete saccharification of sorghum malt without using external enzymes was possible. Increased collaboration between researchers and the industry was suggested.

Industrial malting of sorghum was discussed at length. It was stated that formaldehyde was used to deter the growth of molds during steeping and malting. Automation of the malting process is desirable as it improves the quality of malt. The floats (immature and nonmalted grains) ranged from 0.5 to 1% and sprouts (dried shoots in the malted product) ranged from 1 to 2% and varied between cultivars. The value of sprouts, which contain dhurrin, as a feed supplement to pigs is under study. Box malting was found to be superior to floor malting. Cost of large scale malting plants depended on the approach taken. Indigenous technology and materials could scale down costs. Enzyme production plants might need an investment of 0.5 to 1.0 million ₦ (₦ 1 = US $0.13), based on current prices.

The increased use of white grain sorghum by breweries might result in competition in the market between grain for food and grain for brewing purposes. It was suggested that this problem might be solved by identifying and breeding specific cultivars for brewing purposes.

Nonalcoholic Beverages and Weaning Foods

Uses of Sorghum in Malted and Fermented Foods and Drinks

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The use of sorghum in commercial production of weaning foods and beverages in Nigeria is in its infancy. Food Specialities (Nigeria) Ltd. has just begun to utilize sorghum as a source of its malt extract component in its product formulations. It has been estimated that in Nigeria, there is a deficit of sorghum grain for commercial utilization to the tune of 9 48 000 t a^{-1}. Sorghum grains with golden-yellow color and low tannin level are preferred for malt extraction. Storage of sorghum grain can increase grain moisture content from 10 to 13%, and it is costly to avoid insect infestation. Negligible quantities of foreign matter, uniform size, and germination of grain lots are important for industrial malting of sorghum. Diastatic power of sorghum is far below that of barley. Therefore, selection and production of sorghum cultivars with high diastatic power is desired. The qualities of malt extracts from sorghum and barley are comparable. Consequently, the potential use of sorghum malt extract in the manufacture of food drinks, baby foods, dietary foods, is very promising. Considering the increased commercial utilization of sorghum, Standards Organisation of Nigeria (SON) would need to establish practical and enforceable quality standards and specifications, in collaboration with researchers and users.

Potentials of Using Sorghum in the Production of Weaning Foods

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The production of weaning foods utilizing sorghum and cowpea, and sorghum and soybean foods was described, and the products were evaluated. Sorghum grains steeped for 18 h and cowpea steeped for 12 h, were germinated, dried, kilned, and milled to obtain debranned malt flour (<60 BS mesh). Steeped ripe grains of sorghum were allowed to germinate for 3 days and cowpea grains were germinated for 24 h. The sorghum and cowpea malted flours were blended in a proportion of 7:3 to give malted weaning food (MWF). Pearled sorghum grain was pulverized and blended with flour from pearled cowpea in the proportion of 7:3. A 30% cold water slurry of this mixture was roller dried to obtain roller dried food (RDF). The cooked paste viscosities of the malted flour

and MWF were significantly lower than those of the flour from nongerminated grains and RDF. The MWF had 10% protein and a protein efficiency ratio (PER) of 2:3.

Preparation of sorghum and soybean *ogi* (weaning food in Nigeria) involved steeping sorghum grain for 24 h followed by wet milling and Alteration through a vibroscreen (<211 μ). Soybeans were dried at 110°C for about 1 h followed by d ehulling and cooking in excess water. The detoxified and cooked soybeans were wet milled and the slurry was filtered through a vibroscreen (< 211 μ). The sorghum and soybean slurries were mixed by dry weight proportion of 7:3 and left to ferment naturally priming with 24 h sorghum step liquor. It was fermented till the required acidity (0.6%) by weight of lactic acid was reached. Sugar (9%), vitamins, and minerals were added to the fermented product which was then spray dried. The dried product was sieved and packed. During further trials, cost of drying was reduced by dewatering the sorghum and soybean slurries to give cakes. The cakes were blended and reduced in a hammer mill. The dried granules were milled into powder and mixed with other desired ingredients like vitamins and minerals. The sorghum and soybean compared well with popular commercial weaning foods in the market, and had 16-21% protein.

Use of Sorghum in the Preparation of Weaning Foods

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Ogi is the most popular traditional weaning food in Nigeria and is prepared from sorghum, fermented maize, millet or rice mash. Sorghum *ogi* contains 6-10% protein and about 90% starch. The quality of *ogi* can be improved by cofermenting sorghum with soybean in a ratio of 3:1. Ready-to-eat weaning foods can be prepared from sorghum by various methods: drum drying a cooked paste, extrusion cooking, and baking of dough into cookie-like products. Industrial production of these foods requires effective planning for quantity and quality of sorghum grain.

Evaluation of seven sorghum cultivars for various malting properties indicated significant variation between cultivars. Modification of endosperm in cv SSV3 was reduced with increasing grain bed layer thickness. Attention should be paid to problems such as these, while selecting cultivars for malting purposes.

Use of Sorghum in Infant Weaning Practices: The AERLS Experience

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The weaning practices in Nigeria were briefly reviewed. It was recognized that sorghum grains contain poor quality protein leading to nutritional deficiencies which can be rectified by supplementing sorghum diets with legumes. A study conducted by Agricultural Extension and Research Liaison Services (AERLS) in three villages around Zaria indicated that sorghum was mostly dry milled into flour and grits. Wet milling of sorghum alone or with corn or millet was common. The wet milled product might be fermented. Roasting and popping of sorghum were also common. The study found that *tuwo* and *kamu* were the major traditional products prepared from sorghum in these villages. The focus of AERLS food technology and home economics programs has been to continue to modify or replace the ingredients of traditionally known weaning foods so that they are culturally acceptable and nutritionally better. AERLS has recommended a range of sorghum based weaning foods supplemented with soybean, cowpea and groundnuts. A variety of soups and snack foods were also formulated.

Fermented Infant or Weaning Food Formulations

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Malnutrition of infants is common in Nigeria and many other developing countries. Fermented infant and weaning food called *ogi* made from sorghum or maize has been used in Nigeria for ages. The product that takes the strength of the lactic acid fermentation however, has not enjoyed commercialization. Industrial manufacturers are not using fermentation techniques because of lack of appreciation of the advantages of the lactic acid fermentation imparted properties and the long fermentation procedures with adequate quality controls. The following guiding principles would be useful in the formulation of weaning foods. An overall balance of aminoacid pattern, metabolizable energy, utilizable protein, vitamins, and minerals in the product should be achieved. Raw materials of optimum food value like white sorghum, maize, millet, rice, cowpeas, groundnut, and soybeans could be considered to balance the formulations with milk and sugar to taste. Adequate level of fermentation will result in a microbiologically stable product of pH 3.5-4.0. The dehydrated product should be packed under hygienic conditions. The use of boiled and cooled water for reconstitution must be advocated to avoid contamination.

Industrial Products from Sorghum

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Sorghum grain and stalk offer a vast scope for industrial utilization. Sorghum can be used to make several industrial products such as starch, sugars, beverages, alcohols, and chemicals. Sorghum starch can be converted to glucose, alcohols, organic acids, and several other chemicals useful to other industries. Sweet sorghum can yield alcohol and sugars. Sorghum can also be used for the production of cellulose and paper. Increased utilization of locally produced sorghum will benefit farmers through increased demand for raw materials and help the economy of developing countries by reducing the need for imports.

Summary of Discussions

It was mentioned that food companies could pay premium prices for grain with low amount of foreign matter and other desired attributes. Storage of grain poses problems, especially in the humid tropics. Initial values of germinability in the laboratory might not correspond with final germination values in the malting plant, after storage, due to loss of viability. Storage quality of the grain should be considered as an important selection attribute.

There were questions on the aminoacid profile of the *ogi* product obtained after wet processing and drying. It was clarified that such nutritional losses are offset by the use of cereal and legume combinations which can complement the deficiencies and provide a rich balance. Federal Institute of Industrial Research, Oshodi (FIIRO) has modified its earlier technology of *soy-ogi* production, and the currently recommended technology involves less expensive locally fabricated equipment. The long term nutritional effects of weaning foods are under study. It was pointed out that in certain urban areas mothers stop breast feeding as early as 4 months, and hence the industrial production and nutritional quality of weaning foods is important

Questions were also raised on the justification for use of sorghum for industrial chemicals in the face of competition with uses for human and animal consumption, especially when production is inadequate. It was clarified that research has shown the feasibility of utilizing sorghum for several industrial products. For example in Mexico, sorghum is being used to manufacture starch. However, local market economics dictate the final choice of raw material.

Finally, it was pointed out that food technologists should experiment with a range of sorghum cultivars in collaboration with breeders. Variation between cultivars could have drastic effects on the experimental results. It might be easier and useful to identify different cultivars for different end uses.

Forage and Feeds

The Potential of Sorghum Straw as a Livestock Feed in Nigeria

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Sorghum is a major cereal in the northern Savannahs of Nigeria where most of the ruminant livestock occur. Vast quantities of bulky straws are left behind on the farm annually which serve as valuable feed for livestock in the dry season.

Sorghum straw, like other cereal straws, has a low nutritive value due to low crude protein (3.8-7.5%), and high cell wall (over 70%) content. Although differences in nutritive value of sorghum straw due to cultivars exist, no correlation was established between grain yield and nutritive value of the straw. Studies on the feeding value of 13 sorghum cultivars of the Institute for Agricultural Research (IAR), Samaru, showed that high cell wall content, especially of lignin, affected the in vitro organic matter digestibility of the straw.

Crop residue grazing is the major mode of utilization of sorghum straw in Nigeria. Other important methods of utilization involve, stall feeding of supplemented, treated or nontreated straw. These methods of utilization were discussed and suggestions for enhanced utilization were made.

Feed Uses of Sorghum Grain and Stover

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The prospects of utilizing sorghum for the livestock feeds industry were reviewed considering the current nutritive value of the crop. Sorghum grains have been widely used in livestock feeds. High tannin sorghum grains are however, not efficiently utilized by monogastric animals. Vast quantities of sorghum stover (crop residue) have been utilized in Nigeria in ruminant diets to maintain animal liveweights during the dry season. The stover is low in protein and high in ligno-cellulosic compounds. Various forms of nonprotein nitrogen and protein, with or without molasses, and minerals, have been tested as supplements to the stover with varying degrees of success. The inconsistency of the results may in part be due to differing standards or approaches or the varying levels of inclusion of the different components. For instance, the depressant influence of some supplements of intakes at certain inclusion levels may result from a substitution effect. Also, nonprotein nitrogen, and proteins with their differing degradation characteristics are likely to cause differences in results. Nevertheless, results generally indicate that, when sorghum stover were fed alone, animals lost weight but when supplemented with moderate quantities of protein, nitrogen and minerals, animal liveweights were maintained, and in some cases increased.

Utilization of Sorghum Grain in Livestock Feeds

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On the basis of current knowledge, the potentials and problems of utilizing sorghum grain in commercial feeds were reviewed. The ban on import of maize, which has so far been the main source of energy for livestock feeds in Nigeria, resulted in a shift towards the use of sorghum. With increased use of sorghum by the breweries and millers in Nigeria, the by-products are becoming available for livestock use. A review of the literature indicated that grain sorghum is approximately equal to maize as feed grain for most classes of livestock. Some cultivars of sorghum are low in lysine, methionine and threonine, and their supplementation in livestock feed was considered. Methods for detoxification of tannins were reviewed. Processing of sorghum grain for livestock was also considered. Utilization of sorghum grain for poultry, rabbits, swine, and ruminants was reviewed.

Feeding Value of Sorghum and Its By-products to Livestock

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Three-fourths of the costs of producing livestock are feed costs. Feed value determines meat value. A comparative analysis of various feed grains as economical sources of nutrients indicated that sorghum is the cheapest source of energy at the prevailing price. Grain sorghum is very similar to shelled corn in chemical composition except that most grain sorghum is slightly higher in protein and contains little, if any, of carotene. Grain sorghum can be used to replace as much as 50% of the corn in the ration for most livestock without affecting animal performance. If grain sorghum is used to replace all the corn in the ration, feed efficiency may be reduced by as much as 10% or possibly more. However, this can be overcome by steam rolling or feeding as high moisture

grain. For most classes of livestock, grain sorghum should be rolled or ground. Bird proof sorghum varieties proved to be of inferior feeding value because of their low palatability and digestibility.

Methods of Processing Sorghum for Livestock Feeds

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Sorghum [*S. bicolor* (L.) Moench] without tannins has 95% or greater feeding value than the feeding value of yellow dent maize for all livestock species. Sorghum must be processed to achieve optimum feed efficiency. Methods of processing range from dry grinding to steam flaking, popping, micronizing, reconstitution, early harvesting, and high-moisture storage. Processing improves feed efficiency by disrupting the peripheral and corneous endosperm cells of the sorghum kernel to expose the components to digestive fluids. Sorghum hybrids vary in nutritional value. Brown bird resistant sorghums contain condensed tannins and have lower feed efficiency. Sorghums without a pigmented testa do not contain any condensed tannins. A clorox bleach test can be used to estimate the number of seeds with a pigmented testa present in market samples.

Sorghum: Feed Grain of the Future in Nigeria

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Sorghum is one of the major feed grains available in Nigeria. It has similar nutritional and milling qualities as maize.

The importance of sorghum grain increased recently with the ban on import of maize, wheat, and barley malt. Competing industrial users are now compelled to exploit the use of sorghum as a substitute raw material. It was estimated that feed grain (maize and sorghum) requirement in Nigeria by the year 1995 would be about 1.7 million t. Maize commands a premium price due to its versatility and greater demand by the high value added industries.

This paper, after reviewing the facts and figures, concluded that within the next five

years sorghum would have replaced maize entirely as the energy source in the Nigerian feed industry.

Summary of Discussions

Methods of detoxifying tannins in sorghum grain were discussed at length. However, it was pointed out that, the percentage of brown sorghum present in Nigerian market samples is very low. Phostoxin has been effectively used to protect grains from insect damage during storage.

Shortage of fodder is acute during the dry season and hence production of cattle feed blocks using molasses should be encouraged. It was pointed out that relatively more leafy straw is desirable. Stover feeding helps the animal to maintain its weight but cannot fatten it. In situ feeding of animals with stover, results in under utilization. It is possible to improve efficiency of utilization by chopping, shredding, and treating the stover, but it was felt that under the local conditions the process is cumbersome and expensive.

Recommendations

Recommendations

I. Milling and composite flour products

A. Four types/levels of milling technologies are currently used in Nigeria:

1. Modified wheat milling plants which are loo large and not flexible to mill other grains. These are noneconomic, particularly when sorghum grain is in short supply.
2. Medium scale mills which arrived after the ban on cereal import. These mills are versatile and are operating well. However, there is considerable under utilization which might increase due to recent import of several such mills.
3. Locally fabricated small to medium scale mills that tend to imitate type 2 but need improvements: Local manufacturers would need a lot of assistance to produce machines comparable to type 2.
4. Mechanized custom milling using small diesel engines: There is a dearth of spare parts like bearings, grinding plates etc.

B. It is possible to substitute wheat with sorghum upto 50% level for production of biscuits. However, production of sorghum flour of the right particle size (90-120 μ) and quality is a problem. Commercial mills are able to produce sorghum flour of particle size 200-250 μ and extraction of finer flour is difficult and costly. Biscuit manufacturers cannot afford additional price increases. Flour particle size is an inherent quality of the grain.

C. Sorghum and wheat composite flour biscuits pose more breakage problems due to poor binding properties of the dough. Locally produced composite flour and biscuits are competing with imported or smuggled wheat flour and biscuits.

D. Optimum composition of flour for composite bread production is sorghum 20:80 wheat, using locally produced wheat. However, with the inclusion of certain ingredients such as pentosans, 50% substitution can be achieved. Therefore, it might be useful to characterize pentosans of sorghum and seek to increase pentosan levels in the flour by breeding or processing (e.g., malting).

E. Cakes prepared with 100% sorghum flour become brittle in 24 hours. Optimum composition of composite flour for cakes is yet to be standardized.

F. It is desirable to select sorghum cultivars with the following grain quality attributes:

1. Improved mechanical milling properties, i.e., with higher proportion of hard and vitreous endosperm, that lead to higher extraction rates of good quality flour.
2. Higher pentosan content which might improve baking quality.

II. Nonwheat flours and other novel products

A. There are claims that sorghum 30: 70 cassava (starch) flour can be used for a type of nonwheat bread. However, cassava starch is costly and only limited quantities are available in the country.

B. Sorghum flour can be used up to the level of 100% to make products like *chin*

chin (a Nigerian snack), cup cakes and other forms of snacks. A mixture of sorghum flour and cassava starch can also be used in these products.

C. It is useful to identify sorghum cultivars that can give the best results in the production of various bakery products.

D. 1. Pop corn is in short supply and there is an increasing demand or potential for the production of pop sorghum. Sorghum cultivars suitable for popping are known and their production should be encouraged.

2. Extruded products have not become commercially popular due to the high cost of the equipment. However, the potential of extrusion technology is under investigation at IITA.

3. Little work has been done on techniques such as micronization and pregelatinization which might improve digestibility of sorghum products and compatibility of sorghum starches with tuber starches in preparing traditional pasted products, *e.g.,fufu* (a Nigerian snack).

4. There has been no local Research and Development activity in the technology of flaking and imported technology is expensive.

E. 1. Nigerians should seriously consider the possibility of changing their cultivated habit of consuming European type bread and other such products.

2. Marketing strategies are required to develop effective methods of promoting nonconventional and novel products, e.g., 100% sorghum bread, cakes, and biscuits. Educational programs are required to reinforce this habit among school children. Government should become actively involved in sponsoring promotion programs that will increase consumption of such novel products.

III. Beverages

A. Lager beer brewers in Nigeria are currently using sorghum extensively. Sorghum is also used to make food drinks.

B. There is scope for substitution of barley malt extract in weaning foods and some products are under large scale testing.

C. Current sorghum brewing techniques have been based on barley brewing technology with suitable modifications. There is an indication of the feasibility of brewing lager beer from sorghum malt without the addition of exogenous enzymes. However, this needs further study, more corroboration and confirmation.

D. Currently, sorghum variety SK 5912 is being used by the brewing industry for grits, malt, etc. However, brewers need the following attributes of the grain for gritting and malting:

1. Hard endosperm types for gritting and medium to soft endosperm types for malting, free from molds, and aflatoxins.
2. Grains for producing grits should have low fat content (<3.5%). Grits with low fat content (<1%), high extract, low polyphenol, and adequate protein (8-9%) levels, are desirable for brewing purposes.
3. Grains suitable for malting should exhibit fast water absorption rate, good germination (%), high enzyme production, high malt extract (not less than 80%), low production of rootlets, and low growth of molds.

E. The Current large-scale malting techniques need to be improved and further studies are recommended.

F. National and international sorghum research programs should identify suitable cultivars for use in malting, brewing, and other food industries.

G. The by-products from brewing and malting industry include: spent grain, spent yeast, $C0_2$, rootlets and dhurrin; methods of optimal use of these by-products should be explored.

H. Other chemical products of potential industrial application that can be extracted from sorghum include starch for syrups, ethanol (from sweet sorghum), and furfural for resin production. Universities and research institutes should explore the feasibility of their industrial production.

IV. Forage and feeds

A. Straw is the major component of the plant, for crop residue feeding to ruminants in Nigeria. The chemical composition of sorghum straw and the resultant nutritive value are largely influenced by the leaf content which in turn varies with cultivar. Other factors affecting straw chemical composition are the type and level of fertilizer applied, weathering effects, and general locational effects. In general, sorghum straw is a bulky low-protein feed high in lignocellulosic material. The tannin content of the plant material studied (straw) did not adversely affect the nutritive value in ruminants.

B. Chopping and shredding of the straw will facilitate handling (transportation), and improved animal utilization. However, it will increase handling costs. There is a need to encourage local fabrication of manually operated straw choppers for distribution. ICRISAT could collaborate with national research institutions in the fabrication of low cost shredders.

C. The use of fertilizer grade urea for crop residue treatment has been successfully introduced into some parts of the country. There is a need to disseminate this technology among a broader spectrum of farmers. Further research is required on treatment procedures requiring the use of less water and eliminating the use of polythene sheets as cover material for treated straw. More research should be done on the effects of long term feeding of treated straw using appropriate supplements.

D. Protein blocks comprising molasses, bran, and appropriate binders [e.g., $Ca(OH)_2$] are a cheap method of supplementing ruminants grazing on sorghum straw. Additional research is required on block-making methods to enhance animal acceptability, better block-drying methods and also the effect of long term utilization of the block by grazing ruminants.

E. Sorghum spent grain is an effective feed supplement to straw. There is a problem of quality standardization of the spent grain in view of varying levels of nondisclosed grain mixtures used by the breweries. Appropriate drying methods of the spent grain must be locally developed.

F. Forage legume intercropping is an effective means of integrating livestock into the sorghum cropping system and it should be encouraged to enhance sorghum residue quality and improve soil fertility.

G. Short sorghum cultivars should be encouraged since these are generally more leafy and high yielding in grain.

H. It is recommended that sorghum grain for feed should be handled as follows:

   1. Fed whole to poultry from the grower stage.
   2. Cracked for other poultry category and cattle.
   3. Other grain processing methods may not be economically justifiable at the moment.

I. More research work should be carried out on the nutrient content of the various sorghum grain and malt by-products (bran, germ, sprouts, and floats).

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ISBN 92-9066-188-7 ICR 90-0031