

Crop Utilization and Marketing



An Evaluation of New Market Development and Marketing Strategies on Sorghum and Millet Farmers' Income in Tanzania and Zambia

Project OSU 200
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Summary

The present marketing research on sorghum and millet in Tanzania and Zambia contributes to the four INTSORMIL project objectives: promoting economic growth, improving nutrition, increasing yields, and improving institutional capacity. The main objective of this marketing project was to evaluate the effects of new market developments and new technology adoption on economic growth, productivity, and smallholder incomes. One of the keys to economic growth is increasing productivity through new technology. Linking farmers to markets is fundamental to the adoption of new technology that can increase farm output, productivity and income.

Four market developments for sorghum and millet offer opportunities to increase farmers' income: (1) the agro-food industry, especially food processing, (2) feed concentrates, (3) clear beer brewing, and (4) energy markets. Some of these markets such as sorghum based clear beer brewing and feed concentrates can be expected to grow rapidly (10 to 15 percent or more per year) in the near future while others such as fortified foods may grow more slowly. If small farmers are to take advantage of these new market developments they will need to be better integrated into commercial supply chains.

Closer coordination between producers and commercial end-users on supply chain management has begun with clear beer brewing in each country. Beer brewers have developed a sorghum based clear beer called Eagle Lager brand. Eagle Lager was introduced in Zambia in 2005 and in Tanzania in 2007. Early results in Zambia indicate that sales are exceeding expectations and that clear beer brewing has developed as a new market opportunity for sorghum producers. Lack of a market is no longer the main supply chain constraint. Rather, sorghum supply has become the main constraint. Based on interviews with key participants in the supply chain the major constraints are adequate quantities, reliable supply, high quality product and reasonable prices.

A comparison of crop budgets between farmers using traditional and new technology is presented in Tables 1 and 2 for Tanzania and Tables 3 and 4 for Zambia. The traditional technology is based on what most farmers are using at the present time in the study areas. The new technology is based on recommendations by INTSORMIL and host country research institutes. These new technologies include improved seeds, manure/fertilizer, and ridge tilling/basins to conserve moisture. Crop yields, gross returns, variable costs, profits and profit per man day all increase with the new technology package. In most cases the increases are dramatic. A large gap exists between the traditional and new technology results. The new technology returns are higher; however, the risks (e.g., market, production, and financial) are also higher which may explain the gap between use of the traditional and adopting the new technology. Farmers will examine the risk to return ratio when choosing to adopt new technology. Finding ways to lower the risk relative to the return will increase technology adoption. Linking farmers to dependable markets is key to reducing the risk to return ratio.

Quantitative analyses of survey data generally concur with past findings from research on the adoption of agricultural technologies. A combination of human capital (education) and economic assets (farm size, farm income and dwelling index) and background characteristics (sex) influence access to new information and affect the ability to adopt new technologies. In general, adopters appear to be those who are willing and able to accept the risks associated with adoption of new technologies. Thus, interventions to promote adoption of new sorghum and millet technologies need to invest in programs that reduce perceptions of risk such as educational programs and risk-reduction strategies such as provision of credit.

The present research has contributed to strengthening the administrative and research capacities of the collaborating universi-

ties. The sub-contracts provided very important resources to facilitate applied research on major crops in each country. The faculty and students have gained valuable understanding of sorghum and millet marketing, agribusinesses such as food processors, and the management of all aspects of a field research project. In addition, the interaction among the researchers has produced capacity building benefits to the faculty and students from SUA and UNZA as well as to the U.S. based researchers.

Objectives, Production, and Utilization Constraints

The main objective of this marketing economics research project at The Ohio State University was to evaluate the effects of new technology and marketing strategies on sorghum and millet farmers' income in Tanzania and Zambia. Past agricultural research and development experience indicates that adoption of improved technologies in the absence of cash markets is rare. Thus for the purposes of our study it was assumed that new markets for sorghum and millet would drive the adoption of new technologies and lead to enhanced output, farmer incomes, and improved rural livelihoods. The second year close out project objectives were: (1) to conduct further analyses of the farm level data that was collected in year one and, (2) to conduct an in-depth study of the entire value added supply chain for one of three potential valued added markets for sorghum and millet. We selected the sorghum based clear beer supply chain for study in the second year of the project because of its new and dynamic characteristics and because this value chain is emerging simultaneously in both countries.

The main production constraints addressed were low technology adoption, low productivity, low profitability, low income, and household food insecurity. The main utilization constraints addressed were perceived lack of reliable markets, linking small farmers to markets, erratic supply, poor rural infrastructure, and high costs and poor quality in the sorghum supply chain.

Description of Methods of Work Used

This marketing research project was carried out in cooperation with the Department of Agricultural Economics and Agribusiness, Sokoine University of Agriculture (SUA), Faculty of Agriculture, Morogoro, Tanzania and the Department of Agricultural Economics and Extension Education, the University of Zambia (UNZA), School of Agricultural Sciences, Lusaka, Zambia. A questionnaire was developed with host country collaborators to survey farmers in a major sorghum and millet producing area in each country (Dodoma in Tanzania and Siavonga in Zambia). It was assumed that some of the farmers in each area would be using new technologies and others would be using traditional technologies for producing sorghum and millet. Usable questionnaires were completed with over 100 farmers in each country. Additional interviews were completed with key informants in the private and public sectors in each country to obtain valuable insights about new markets and the adoption and profitability of new sorghum production and marketing technology. Key informants included farmers, input supply firms, sorghum buyers, processors, and wholesalers in the sorghum beer brewing and food processing value chain. Public sector interviews included USAID/Tanzania, USAID/Zambia, sorghum and millet researchers (e.g., INTSORMIL), government policy makers, statistical agencies, TechnoServe, CARE, and others such as

the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

The sorghum based clear beer market was selected for additional supply chain analysis because of its high growth potential. A small number of surveys were completed with retailers, wholesalers, brewers, warehouses, transporters, local buyers, farmers, and others engaged in the clear beer supply chain. All aspects of information flows (e.g., prices, qualities, varieties), promotion flows, ownership flows, product flows, payment flows, and constraints in the supply chain were examined. A diagnostic report examining the problems and constraints of the supply chain is being prepared.

Research Findings and Project Output

New Market Opportunities for Sorghum and Millet: Four market developments offer opportunities to increase farmers' income: (1) the agro-food industry, especially food processing, (2) feed concentrates, (3) clear beer brewing, and (4) energy markets. Some of these markets such as a sorghum-based clear beer brewing and feed concentrates can be expected to grow rapidly (10 to 15 percent or more per year) in the near future while others such as fortified foods may grow more slowly. The energy market for sorghum is a longer term development that may grow rapidly but also carries higher risk because of volatile world energy markets.

Survey Results of Sorghum and Millet Farmers: In general, the households surveyed (130 in Dodoma Region, Tanzania; 116 in Siavonga Region, Zambia) have little education, small farms, low crop yields, and low incomes. Low levels of household education (6.6 years) slow the dissemination and adoption of new technologies and participation in new market opportunities. Average farm size including fallow and virgin land was 2.6 hectares in Tanzania and 2.99 in Zambia. Household income from all sources averaged about U.S. \$430 in Tanzania and \$260 in Zambia. Most households had several sources of income with farm income being more important than off-farm income in Zambia but the reverse in Tanzania. Average yields per hectare were 280-430 kg/ha for maize; 330-360 for sorghum; and 305-320 for millet. Overall, crop yields were very low. Most growers of maize (76%); sorghum (79%); and millet (95%), were net-buyers, indicating that food security was a major problem.

Adoption of New Technologies: The use of inorganic fertilizers and other agro-chemicals such as herbicides in agriculture was not common. However, 17 % of the farmers applied manure on maize, 30% on sorghum, and 52% on millet. Use of improved varieties varied by country with 59% of respondents in Tanzania and 30% in Zambia growing improved sorghum varieties; and 33% in Tanzania and 6% in Zambia using improved millet varieties. Tanzanian farmers indicated that they preferred the quality of local sorghum varieties, and drought tolerance and early maturity of improved sorghum varieties. The most commonly used improved sorghum varieties were Kuyuma and Sima in Zambia, and Pato, Tegemo, and Mesia in Tanzania. Most farmers used their own seed which is replanted year after year. The most important tillage practices were animal draft (Zambia) and hand hoe and zero tillage (Tanzania). Using deep tillage, planting basins and ripping to conserve soil moisture was used by very few farmers. Except

for the use of improved sorghum varieties in Tanzania, the use of improved technologies was very low.

Crop budgets using traditional and new cropping technologies were estimated for maize, sorghum and millet for surveyed households in Dodoma Region, Tanzania, and Siavonga Region, Zambia. Crop budgets for Tanzania are provided in Tables 1 and 2. The results indicate that yields and profits are low. Millet was the most profitable crop followed by sorghum and maize. The net profit for millet was 46% and 44% higher than sorghum and maize, respectively; whereas that of sorghum was 0.75% higher than maize. The profit per man day is very low, ranging from US\$ 0.30 to 0.60 daily. New technology adoption increases daily profits from US\$ 0.50 to 1.70 depending on the crop. Crop budgets for the Siavonga Region of Zambia are provided in Tables 3 and 4. The analysis shows that sorghum was the most profitable crop followed by millet and maize. The net profit for sorghum was 246 % higher than maize and 19 % higher than millet. However, the profit per man day is very low-ranging from a loss in maize to about US\$ 0.25 daily for millet. New technology adoption increases profits from US\$ 1.13 to 1.62 depending on the crop.

Analyses of factors that influence adoption of improved technologies generally concur with past findings from research on the adoption of agricultural technologies. A combination of human capital (education) and economic assets (farm size, farm income and dwelling index) and background characteristics (sex) influence access to new information and affect the ability to adopt new technologies. In general, adopters appear to be those who are willing and able to accept the risks associated with adoption of new technologies. Thus, interventions to promote adoption of new sorghum and millet technologies need to invest in programs that reduce perceptions of risk such as educational programs and risk-reduction strategies such as provision of credit.

Clear Beer Marketing and Supply Chain: Eagle Lager was successfully launched on the Zambian market in 2005 and in Tanzania in 2007. The product created a supply chain which has benefited the people and firms involved in the supply chain. Among the beneficiaries are sorghum farmers, sorghum traders, processors (breweries), beer distributors, retailers and Eagle Lager consumers. Farmers have a new commercial market for their sorghum crop. The supply chain members benefit from having more sorghum to buy, transport and sell. Brewers have a new product to market and a new source of sorghum supply. Beer distributors and retailers have another product to sell. Consumers have more choice in the selection of clear beer products to purchase. The supply chain developed by Eagle Lager can be used as a model to study value added markets for other sorghum and millet based products.

Marketing and Supply Chain Problems: Major weaknesses in the production of sorghum and millet were low productivity at the farm level resulting from poor agronomic practices, unreliable rainfall, infrastructural problems that limit competition in grain procurement, and lack of support services to enhance efficiency in production and marketing systems. Marketing problems identified by farmers in the survey were unreliable markets, low producer prices, grain damage due to storage pests, lack of price information and lack of good transportation infrastructure. Detailed analysis of market services available in villages indicates that only 9 percent

of respondents received professional advice on marketing from government departments, private firms, NGO projects, or other farmers. This reveals an apparent imbalance between promoting agricultural production services and marketing services. Whereas increasing production was highly encouraged there was no similar effort to enhance marketing. Major problems in supplying sorghum and millet to commercial channels were inadequate and erratic supply, quality problems, and lack of smallholder access to commercial markets.

Policy constraints: The main thrust of government agricultural policy in both countries has been on maize, the main staple, almost to the exclusion of other grains such as sorghum and millet. Some of the policy incentives enjoyed by the maize sub-sector include output price supports, fertilizer subsidies, and other marketing institutional measures that adversely affect farmer incentives to produce sorghum and millet even in areas where the latter have a comparative advantage.

Project Outputs: The main project outputs from 2005 to 2007 were developing and implementing a farm household survey that included questionnaire design, field testing the questionnaire; training six undergraduate and graduate students plus a supervisor in each country to conduct survey work, completion of 116 and 130 farm household questionnaires in Zambia and Tanzania respectively, and tabulating, analyzing and writing up results; interviewing key public and private sector decision makers in the clear beer supply chain; presenting four seminar papers; writing two case studies; writing six reports and papers; supporting one Tanzanian PhD student on a cost share basis to complete his field research work on the clear beer supply chain; and establishing a successful collaboration with faculty colleagues in Tanzania and Zambia.

Networking Activities

This research has collaborated with INTSORMIL researchers Gary Peterson (Texas A&M), Gebisa Ejeta (Purdue), Medson Chisi (Golden Valley, Zambia), and John Sanders, (Purdue); and other researchers including Mike Weber (Michigan State University), scientists at the Ilonga Research Institute, Tanzania, and faculty at host country institutions. Networking activities included USAID/Tanzania and Zambia, government policy makers, statistical agencies, CARE, TechnoServe and others such as ICRISAT.

Publications and Presentations

Erbaugh, J.M., D.W. Larson, E.R. Mbiha, F.T.M. Kilima, P.Hamukwala, & G.Tembo. 2007. Evaluation of New Market Development and Marketing Strategies on Sorghum and Millet Farmers' Income in Tanzania and Zambia. Presented at International Sorghum and Millet Conference, University of Pretoria, South Africa, April 25-27, 2007.

Chimai, B., B. P. Mulenga, G.Tembo, P. P. Hamukwala, D. W. Larson, and J. M. Erbaugh. 2007. The value-added supply chain for sorghum-based eagle lager clear beer in Zambia. Paper prepared for INTSORMIL University of Nebraska, Agreement Number 25-6805-0003-089, Under USAID Grant no. LAG-G-00-96-90009-00, The Ohio State University Research Foundation RF project No: 60004926. May, 2007, Columbus, Ohio.

- Larson, D.W., J. M. Erbaugh, E.R. Mbiha, F.T.M. Kilima, P. Hamukwala, & G. Tembo. 2006. An Evaluation of New Market Development and Marketing Strategies on Sorghum and Millet Farmers' Income in Tanzania and Zambia. Final Report, Year One, Prepared for INTSORMIL University of Nebraska, Agreement Number 25-6805-0003-089, Under USAID Grant no. LAG-G-00-96-90009-00, OSURF Proj. No: 60004926. September 30, 2006, Columbus, Ohio.
- Larson, D.W., J. M. Erbaugh, E.R. Mbiha, F.T.M. Kilima, P. Hamukwala, & G. Tembo. 2006. An Evaluation of New Market Development and Marketing Strategies on Sorghum and Millet Farmers' Income in Tanzania and Zambia. An Interim Research Report, Year One, Prepared for INTSORMIL University of Nebraska, Agreement Number 25-6805-0003-089, Under USAID Grant no. LAG-G-00-96-90009-00, OSURF Proj. No: 60004926. June 30, 2006, Columbus, Ohio.
- Makindara, J.R., E. Mbiha, F. T.M. Kilima, J. M. Erbaugh, and D. W. Larson 2007. Sorghum based clear beer value chain in Tanzania: A situational analysis. Prepared for INTSORMIL University of Nebraska, Agreement Number 25-6805-0003-089, Under USAID Grant no. LAG-G-00-96-90009-00, OSURF Proj. No: 60004926. May, 2007, Columbus, Ohio.
- Mbiha, E., F.T.M Kilima, D.W. Larson, J. M. Erbaugh, and T. Worley. 2006. Strategic Management Options for Growing Power Foods Ltd: Dar es Salaam, Tanzania." Paper presented at the International Food and Agribusiness Management Association (IAMA) 16th Annual Forum and Symposium, Buenos, Aires, Argentina. June 10-13, 2006.
- Mbiha, E., D. W. Larson, J. M. Erbaugh, and T. Worley. 2006. Strategic Management Options for Growing Power Foods Ltd: Dar es Salaam, Tanzania." Case Presentation to the Agribusiness Master's Program faculty and students, Sokoine University of Agriculture, Morogoro, Tanzania, January, 2006.
- Mbiha, E., Fredy T.M. Kilima, J. M. Erbaugh, D. W. Larson, and T. Worley. 2007. Strategic Management Options for Growing Power Foods Ltd: Dar es Salaam, Tanzania. Paper prepared and submitted to International Food and Agribusiness Management Review (IFAMR).
- Tembo, G., P.P. Hamukwala, D.W. Larson, J. M. Erbaugh, and T.H. Kalinda. 2007. Adoption of improved agricultural technologies by smallholder maize, sorghum and millet farmers in southern Zambia. Paper prepared for INTSORMIL University of Nebraska, Agreement Number 25-6805-0003-089, Under USAID Grant no. LAG-G-00-96-90009-00, OSURF Proj. No: 60004926. May, 2007, Columbus, Ohio.

Table 1. Maize, sorghum and millet crop budgets with current technology adoption in surveyed districts of Dodoma-Tanzania for 2005-2006 agricultural season

Variable	Crop		
	Maize	Sorghum	Millet
Average yield per hectare (kg)	433.05	338.75	321.05
Average farm price (Tshs/kg.) ¹	169.25	200.00	369.31
Average gross return per hectare (Tshs)	74,462	67,753	118,565
Average variable cost per hectare (Tshs)	15,285	9,135	12,167
Average profit per hectare (Tshs) ²	58,180	58,615	106,397
Average man days per hectare	134.9	168.45	164.58
Profit per man day (Tshs)	31.23	314.37	646.55

Source: Survey Data, 2006 Exchange rate equals Tshs 1,100/US\$.

Table 2. Maize, sorghum and millet crop budgets with new technology adoption in surveyed districts of Dodoma-Tanzania for 2005-2006 agricultural season

Variable	Crop		
	Maize	Sorghum	Millet
Average yield per hectare (kg)	5,000	3,500	2,500
Average farm price (Tshs/kg.)	169.25	200.00	369.31
Average gross return per hectare (Tshs)	846,250	700,000	923,275
Average variable cost per hectare (Tshs)	750,410	535,885	538,917
Average profit per hectare (Tshs)	95,480	164,112	384,357
Average man days per hectare	193.53	232.57	205.75
Profit per man day (Tshs)	495.24	705.64	1,868.08

Source: Survey Data, 2006 Exchange rate equals Tshs 1,100/US\$.

Two crop budgets for each of the three cereal crops – maize, millet and sorghum – for Tanzania’s smallholder agriculture are presented. For each crop, one budget assumes potential input use and yield levels whereas the other uses actual input use and yield levels. The potential budget is drawn from conditions recommended by researchers for this level of management. These new technologies include improved seeds, manure/fertilizer, and ridge tilling/basins to conserve moisture. The actual budget is drawn from actual survey data from farmers in Dodoma region in January, 2006.

Table 3. Maize, sorghum and millet crop budgets with current technology adoption in surveyed districts of Siavonga region-Zambia for 2006-2007 agricultural season.

Variable	Crop		
	Maize	Sorghum	Millet
Average yield per hectare (kg)	279.78	362.19	306.61
Average farm price (ZMK/kg)	760.00	960.00	960.00
Average gross return per ha (ZMK)	212,633	347,702	294,346
Total variable cost per hectare (ZMK)	418,846	336,000	216,000
Average profit per hectare (ZMK) ³	-206,213	11,702	78,346
Average man days per hectare	106.00	112.00	72.00
Profit per man days (ZMK)	-1,945	105	1,088

Source: Survey Data, 2006 Exchange rate equals Zambian Kwacha (ZMK) 4,100/US\$.

¹ Kariakoo is the largest consumer market in Tanzania located in Dar es Salaam, grains traded in this market come from all regions and its prices are arguably a good reflection of commodity prices in Tanzania. The farm prices were adjusted for transportation cost between Dodoma and Dar es Salaam.

² Average profit per acre is the average gross return minus the variable costs of production. The average profit per acre is the return to the fixed costs of production such as land and management.

³ Average profit per acre is the average gross return minus the variable costs of production. The average profit per acre is the return to the fixed costs of production such as land and management.

Table 4. Maize, sorghum and millet crop budgets with new technology adoption in surveyed districts of Siavonga region-Zambia for 2006-2007 agricultural season.

Variable	Crop		
	Maize	Sorghum	Millet
Average yield per hectare (kg)	1,550	800.00	700.00
Average farm price (ZMK/kg)	760	960	960
Average gross return per ha (ZMK)	1,178,000	768,000	672,000
Total variable cost per hectare (ZMK)	852,550	303,500	323,912
Average profit per hectare (ZMK)	325,450	464,500	348,087
Average man days per hectare	70	70	70
Profit per man days (ZMK)	4,649	6,636	4,973

Source: Survey Data, 2006 Exchange rate equals Zambian Kwacha (ZMK) 4,100/US\$.

Two crop budgets for each of the three cereal crops – maize, millet and sorghum – for Zambia’s smallholder agriculture are presented. For each crop, one budget assumes potential input use and yield levels whereas the other uses actual input use and yield levels. The potential budget is drawn from conditions recommended by researchers for this level of management. These new technologies include improved seeds, manure/fertilizer, and ridge tilling/basins to conserve moisture. The actual budget is drawn from actual survey data from farmers in Siavonga district in November, 2005. Prevailing market prices, as reported in the Ministry of Agriculture and Cooperatives crop budgets, were used in the computations. Maize input and output estimates were obtained from the Ministry of Agriculture and Cooperatives crop budgets. The potential yields for sorghum and millet were obtained from FAO (2003).

Chemical and Physical Aspects of Food and Nutritional Quality of Sorghum and Millet

**Project PRF 212
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Summary

This project has focused on improvement of nutritional and grain quality of sorghum and millet, and their processing to competitive products for the West Africa Sahelian marketplace. The overall aim of the research is to make sorghum and millet more competitive grains for human and animal nutrition and for enhanced utilization in traditional and processed foods. In the period 2001 to 2007, major advances for PRF-212 were in five areas involving grain quality improvement and processing: 1) a mechanistic understanding of the basis of the comparably lower raw and cooked starch digestibility of sorghum grain and strategies to improve it, 2) grain quality improvement of the high protein digestibility, high-lysine sorghum mutant (collaboration with G. Ejeta), 3) an understanding of the relationship between starch amylopectin fine structure and its retrogradation property and a strategy to improve staling quality of sorghum and millet, 4) discovery of how to make non-wheat cereal storage prolamin proteins behave as wheat gluten to make yeast-leavened products, and 5) development of new pre-gelatinized sorghum thin and thick porridge flours that were preferred in sensory trials in Niger over traditionally-processed porridges. This project PI has a number of collaborations with PIs in West Africa associated with improving or developing new sorghum and millet-based products for sale to urban consumers. These are summarized both in this and the West Africa regional reports. A number of students and post-doctoral research associates were trained in this period including Betty Bugusu, a Kenyan doctoral student who worked on the sorghum starch digestibility

problem, and Moustapha Moussa, a Nigerian master's student who developed the pre-gelatinized "instant" porridge flours.

Objectives, Production and Utilization Constraints

Objectives

- Determine the relationships among the physical, structural, and chemical components of grains and food to improve food and nutritional quality of sorghum and millet.
- Determine the biochemical basis for the relatively poor protein and starch digestibility of sorghum grain and many cooked sorghum products.
- Develop laboratory screening methods for use in developing country breeding programs to evaluate and improve the food quality characteristics of sorghum and millet grain.
- Optimize processes and improve quality of commercializable sorghum and millet processed foods, and facilitate transfer of technologies.

Constraints

Research on food and nutritional quality of sorghum and millet grains is necessary to improve grain quality characteristics and stimulate commercial processing in developing countries. Factors affecting milling qualities, food quality, and nutritional value

critically affect other efforts to improve the crop. If the grain is not acceptable to consumers, then grain yield and other agronomic improvements to the crop are likely to be lost. In addition, breeding grains that have superior quality traits will more probably give rise to processed food products that can be successfully and competitively marketed. This is especially true for sorghum that is perceived by some to have comparably poor quality characteristics to other major cereals. The overall goal of this project is to improve food and nutritional quality of sorghum and millet, and their competitiveness, through a better understanding of the structural and chemical components of the grain that affect quality. This knowledge is applied to develop useful methodologies for screening germplasm for end-use quality, develop techniques to make the grain more nutritious, and improve grain utilization through processing.

Research Approach and Project Output

Food Products

Pregelatinized Sorghum Flour Products

In a completed study, M. Moussa (INRAN/Niger) and in collaboration with Dr. LiFu Chen of Purdue's Food Science Department, developed a procedure to produce pregelatinized sorghum or millet flours using a high shear, low pressure mixer for possible commercialization as instant thin or thick porridges. It has clear advantages over traditional processes of having the advantage of using a low-moisture feed stock to produce a dry product similar, but of lower cost, than an extruder, and of higher quality than a drum-dried product. Consumer testing in Niger in four urban and rural sites showed both instant thin and thick porridges were statistically preferred over same flour-prepared traditional porridges (Figure 1). Such high quality instant porridge flours appear to have good potential in urban markets where mid-level consumers are able and wanting to buy more convenience foods. Moreover, pregelatinized flours have good potential for long term storage and low susceptibility to microbial spoilage. This is one project in our

effort to find ways to enhance sorghum and millet markets in West Africa.

Analysis of the physicochemical properties of various optimized instant sorghum porridge flours were conducted and related to sensory acceptability results. Analysis of dynamic oscillation measurements on thick porridge samples via frequency sweep revealed that all instant thick porridges were found to form stronger viscoelastic gels than the local traditionally prepared sorghum MR732 cultivar. As well, analysis of viscosities of thin porridge samples via flow curves measurement show that, at a maximum shear stress of 100Pa, the conventionally cooked MR732 thin porridge had the highest viscosity, while all instant thin porridges were characterized by lower viscosities. Molecular weight distributions of starch molecules showed significant fragmentation of amylopectin in the instant flours, a property thought to confer a smoother, creamier texture to the porridges.

High Quality Couscous and Flour Processing

Over the period, we have continued collaborative efforts to produce high quality sorghum and millet agglomerated products (couscous and other sized products) and flours at INRAN/Niger with a regional strategy and collaborations to commercialize sorghum and millet products. A group of food scientists/technologists from each of the six INTSORMIL-collaborating West Africa countries, and B. Hamaker, have met a number of times to draw up a regional strategy and concept note under the leadership based principally on the institution, Institut de Technologie Alimentaire (ITA) in Dakar, Senegal and PI A. N'Doye.

As described in previous annual reports, PRF-212 and the INRAN Food Technology Laboratory have set up a cereal processing unit at INRAN/Niger to conduct research, demonstration, and testing of sorghum and millet processed products. A central goal of the project has been to optimize the processing system and products, to generate information for entrepreneurial startups, and to work with interested individuals in the private sector. Products

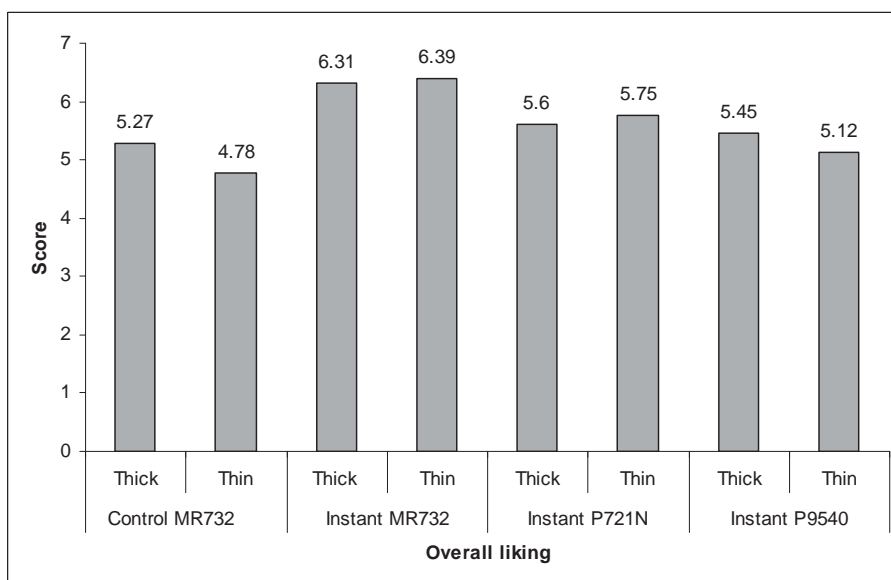


Figure 1. Combined overall liking scores for new instant thin and thick porridges compared to the traditionally processed control porridges

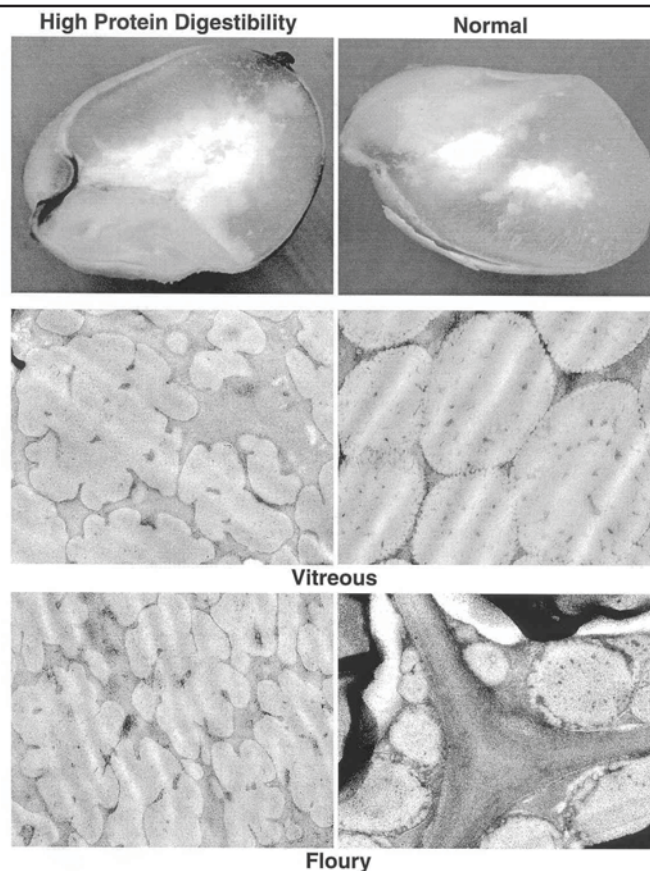


Figure 2. Modified, hard endosperm characteristic of the high protein digestibility/high lysine sorghum mutant (left) with altered protein bodies compared to a related normal, hard kernel line (right)

produced by the unit include high quality flours and grits, and agglomerated products including fine couscous (or dambou), medium couscous, and the coarse particle-size product degue. The core of the sorghum/millet processing unit consists of a commercial scale grain decorticator (dehuller) and hammer mill, a central mechanized agglomerator designed and fabricated at CIRAD, France by J. Faure, a mixer for flour wetting, a couscousserie (steamer), and a large passive solar drying unit. The ability to produce high quality sorghum and millet flours is essential for the commercial success of any flour-based product.

Various market tests have shown high acceptability of couscous and flours produced in the unit. This project collaborates with J. Sanders and O. Botorou and their efforts towards contracting farmers to provide a pure, clean grain source for processed products. This is critical to make consistent, acceptable products.

Nutritional Quality Improvements in Sorghum

We continued work in this period on sorghum nutritional quality improvement with two areas of focus: 1) grain quality (hardness) improvement of Purdue's previously identified high protein digestibility/high lysine sorghum mutant lines [collaborative previously with J. Axtell (deceased) and now with G. Ejeta], and 2) understanding the basis of the comparably poor starch digestibility property of cooked and raw sorghum foods and feed. As described in reports and publications prior to this project period, this mutant genotype contains protein bodies with altered morphology consist-

ing of a deeply folded structure that results in a high rate of digestion of the kafirin storage proteins.

High Protein Digestibility/High Lysine Sorghum Mutant

Figure 2 notably shows that the nutritionally enhanced mutant can be combined with hard endosperm trait, even though its packing is fundamentally different from that of a normal hard sorghum kernel (i.e., the former has starch packed in a discontinuous protein matrix). This modified hard endosperm sorghum mutant is not yet consistent among all panicle kernels, and studies are continuing on this track.

Sorghum Starch Digestibility

Our research findings on manipulations of sorghum starch digestibility showed that, during the cooking process, sorghum proteins form web- and sheet-like structures that constrain gelatinizing starch granules. Thus, cooked sorghum porridge, for example, has a preponderance of protein-starch associated complexes (Figure 3) that appear to restrict starch digestion rate leading to lower starch digestibility. These extended protein structures are formed due to intermolecular disulfide-bonding that creates large polymers, and their rupture improved digestibility. Normal sorghum grain apparently contains a third component that acts to promote protein polymerization that affects starch, as well as protein, digestibility and its identification could lead to more (or less) digestible grains. In the area of animal feed use, starch granule properties were shown

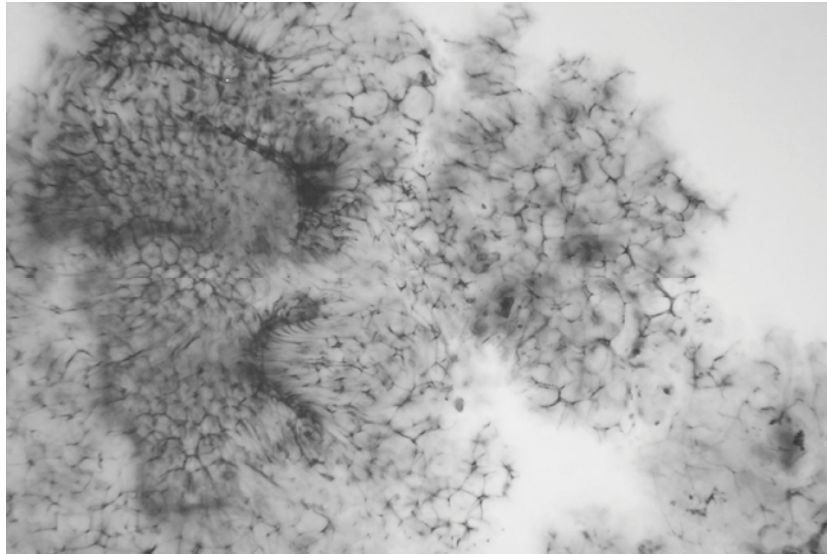


Figure 3. Light micrograph of cooked sorghum flour (1:10 w/v flour-to-water, 20 min at 100°C) stained for starch (pink) and proteins (blue). Gelatinized starch entrapped in protein webs is the last to be digested by α -amylase (Venkatachalam and Hamaker, unpublished)

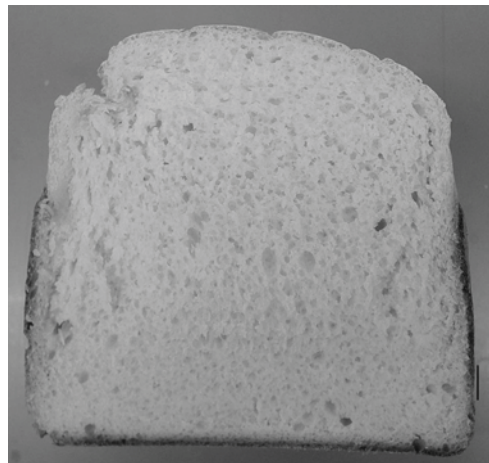


Figure 4. Yeast-leavened breads made from wheat flour (top) and a maize zein-starch model system (gluten-free) (bottom)

to affect raw starch digestibility rates and strategies were discussed to improve this property.

Starch Structure and Keeping Quality of Sorghum

A study on fundamental factors that affect sorghum flour pasting properties showed that starch amylopectin fine structure (lengths and proportions of linear chains), and specifically proportion of the longest chains, was highly correlated ($r=0.92$) to retrogradation (starch reassociation) tendency during storage. This relates starch structure to staling property and may relate to the comparably poor shelf life of some sorghum products (e.g., injera). Noted variability in this property among different sorghum cultivars provides a strategy to improve sorghum product storability through varietal selection.

Making Sorghum and Millet Storage Proteins Behave Like Wheat Gluten?

This study shows that maize prolamin storage protein (zein) can function similarly to gluten, and is the first report of a non-gluten protein yielding a leavened bread-type product. Maize zeins were used as model proteins due to their availability in a relatively pure form. Sorghum and millet prolamins are analogous to zeins. Prolamins were shown to increase in their β -sheet secondary structure similar to wheat gluten when made to be viscoelastic. We found a means to stabilize this increase in β -sheet structure and, when doing so, showed that these proteins could be made to behave similar to wheat gluten in a bread making system to yield yeast leavened bread (Figure 4). This work provides a new opportunity to develop gluten-free products and perhaps ultimately sorghum or millet grains with bread making property.

Networking Activities (2006-2007)

In January 2007, B. Hamaker traveled to Niger, Mali, and Senegal for PRF-212 activities in Niger to promote pre-gelatinized thin and thick sorghum porridge flours to donor groups, and in his West Africa regional coordination role. In April 2007, he traveled to Ouagadougou, Burkina Faso to participate in a regional planning meeting for the new CRSP project.

Publications

Journal Articles

- Tesso, T., Ejeta, G., Chandrashekar, A., Huang, C.P., Tandjung, A., Lewamy, M., Axtell, J.D., and Hamaker, B.R. 2006. A novel modified endosperm texture in a mutant high protein digestibility/high-lysine grain sorghum [Sorghum bicolor (L.) Moench]. *Cereal Chemistry* 83:194-201.
- Aboubacar, A., Yacizi, N., and Hamaker, B.R. 2006. Extent of decortication and quality of flour, couscous and porridge made from different sorghum cultivars. *International Journal of Food Science & Technology* 41:698-703.
- Benmoussa, M., Suhendra, B., Aboubacar, A. and Hamaker, B.R. 2006. Distinctive sorghum granule morphologies appear to improve raw starch digestibility. *Starch/Stärke* 58:92-99.
- Lee, S-H. and Hamaker, B.R. 2006. Cys 155 of 27 kDa maize γ -zein is a key amino acid to improve its in vitro digestibility. *FEBS Letters* 580:5803-5806.
- Nyannor, E.K.D., Adedokun, S.A., Hamaker, B.R., Ejeta, G. and Adeola, O. 2007. Nutritional evaluation of high-digestible sorghum for pigs and broiler chicks. *Journal of Animal Science* 85:196-203.
- Kean, E.G., Ejeta, G., Hamaker, B. and Ferruzzi, M.G. 2007. Characterization of carotenoid pigments in mature and developing kernels of select yellow endosperm sorghum varieties. *Journal of Agricultural and Food Chemistry* 55:2619-2626.
- Mejia, C.D., Mauer, L.J. and Hamaker, B.R. 2007. Similarities and differences in secondary structure of viscoelastic polymers of maize γ -zein and wheat gluten proteins. *Journal of Cereal Science* 45:353-359.

Thesis

- Moussa, Moustapha. 2007. Effect of High Shear, Low Pressure Continuous Processor Technology and Sorghum Cultivars on the Properties of Pregelatinized Sorghum Foods. M.S.

Food and Nutritional Quality of Sorghum and Millet

Project TAM 226
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Summary

Special sorghums have excellent levels of bioactive compounds that are unique with promising positive effects on colon and breast cancer in addition to producing bran with high antioxidant power equal to blueberries. Other positive health benefits relate to slower digestion that has applications in type II diabetes. Supply chain management systems are improving the profitability and acceptance of sorghum/millet based convenience foods for urban markets in Africa, Central America and USA. New, more-efficient, higher-yielding white tan varieties and hybrids have excellent properties for food processing. In West Africa, demand for sorghum and millet products is increasing and contracting among supply chain components is increasing. In El Salvador, small farmers have vertically integrated; they sell their white tan sorghums in the form of baked products. The principle of supply chain management from seed to food products is being implemented. United States value-enhanced white food sorghums developed in part by INTSORMIL, and promoted by the U.S. Grains Council continued to be used in Japanese foods. Several small mills in the US are producing sorghum flour for food markets, especially for celiac-sprue and ethnic groups. Anheuser Busch Redbridge™ lager beer based on sorghum is nationally marketed for celiacs. Tannin and other special sorghums have excellent levels of antioxidant power, high dietary fiber, and impart attractive dark natural color to baked products. They were incorporated into a wide variety of products including BONGOS (a whole grain snack), VITA-BREAD and gluten-free products. Workshops and seminars on food and special tannin sorghums as health foods were presented in South Africa,

Mexico, Central America, Mali and Senegal. The project graduated 11 M.S., 4 Ph.D., 9 short-term trainee students, and produced more than 127 publications. Presentations included international conferences, workshops, commercial companies, and sorghum conferences in Nicaragua, Mexico, El Salvador, Guatemala, Brazil, Japan, Australia and USA.

Objectives, Production, and Utilization Constraints

Objectives

- Develop urban convenience food products from sorghum and millet and assist in developing supply chains to secure a consistent supply of grain for profitable processing
- Determine physical, chemical and structural factors that affect the food and nutritional quality of sorghum; seek ways of modifying its properties or improving methods of processing
- Develop simple, practical laboratory methods for use in breeding programs to assess important grain quality characteristics
- Determine the factors that affect resistance to grain molds and field deterioration in sorghum and devise laboratory procedures to detect genotypes with resistance

Constraints

This project relates quality to measurable characteristics that are used to select sorghum and millets with good traditional and

industrial utilization attributes. It defines quality attributes and collaborates with breeders to incorporate desirable properties into new cultivars at early stages in the breeding and improvement programs. The project finds more efficient ways of processing sorghums and millets into new foods with better acceptability that can generate income for farmers and entrepreneurs.

Research Findings and Project Output

Research Findings

More people understand the need to develop supply chain management schemes to secure grain for processing. Many small entrepreneurs demanding improved quality grain are paying more because grain quality is critically important for their continued success and expansion of markets. Profit for all from the seed to the processor is necessary.

Products and/or Impacts Produced from Projects

Supply chain management is the way to improve adoption of new technologies from cultivars to management practices, provided there is a profitable market for the grain produced. Successful development of this system requires patience and practical programs to educate key managers, farmers and processors. J. Sanders' project on marketing has demonstrated this concept and profitable millet/sorghum foods are being marketed in West African countries.

Similar findings in Central America demonstrated that good quality sorghum produces convenience foods with good taste, appearance and consistent quality at competitive prices. In El Salvador, sorghum flours from improved white tan plant varieties like Sureño, Soberano, and Dorado are used in small bakeries to produce pan dulce, muffins, bread, rosquettes, rosquillos and other variations of these products. The ability to identify preserve food sorghums for processing is necessary for consistent success.

Some producers process their own sorghum into flour and sell baked products in local village markets. These operators plant, harvest, store and process Dorado grain into baked products for sale in local villages. There is significant interest in the larger formal baking industry in San Salvador to use white sorghum flour. Ms. Vilma R. Calderon, Food Technologist, CENTA, worked with a rice miller to process white food sorghum into excellent flour and decorticated products which are acceptable to bakers in San Salvador. The bland flavor of sorghum flour has advantages over corn flour as a wheat flour substitute, and in producing certain types of snacks, i.e., extruded fried potato sticks.

Extrusion processing. Several graduate students demonstrated that whole grain, cracked whole grain and decorticated grain of waxy, heterowaxy and nonwaxy sorghums had significantly different extrusion properties when producing ready-to-eat breakfast cereals and snacks with different degrees of expansion and texture. For example, waxy whole grain extrudates had a softer texture with less expansion than nonwaxy or heterowaxy extrudates. These sorghums have different levels of amylose, and have potential for use in numerous products. Extrusion processing caused

significantly reduced levels of extractible tannins, and reduced antioxidants in sorghum products. The success of commercially extruded Japanese snacks substantiate that sorghum can be easily processed into a wide variety of products.

Bioactive components and health benefits of sorghums. Tannin, black and other special sorghums have relatively large amounts of unique compounds that have significantly positive effects on human health ranging from type II diabetes control to anticancer activities. The bioactive compounds are concentrated in the outer areas of the kernel, and can be easily concentrated by abrasive milling and other processes. They contain powerful antioxidants effective in stabilizing ground meat patties, and have in vitro antioxidant levels similar to many fruits and vegetables. In addition, some have high levels of 3-deoxyanthocyanins which are pH-stable colorants. These compounds have anticancer activities in human cell culture tests. The condensed tannins of sorghum provide strong antioxidant activities; their availability is affected by different processing methods.

Health foods from special sorghums. Our graduate student product development teams won first prize in three consecutive years in the American Association of Cereal Chemistry International Conference for producing BONGOS, "Vita Bread" and CRUNCHCHIPS containing sorghum whole grain and bran. The bran is high in dietary fiber, antioxidants and natural brown or black pigments that impart attractive colors to baked products such as cookies and multigrain breads. A bread that contains high tannin sorghums as a source of antioxidants is currently being sold by a commercial bakery in the USA.

Gluten-free breads for celiacs. A gluten-free bread for gluten intolerant people based on a blend of starches, xanthan gum, tannin sorghum bran, inulin and flax seed produced excellent bread. The inulin improved loaf volume and softened the bread crumb significantly over the control bread, while the dark color of the sorghum bran improved appearance and enhanced nutritional value significantly. Sorghum is sold in a wide variety of celiac foods.

Tan plant food-type hybrid performance and quality trials. Environment and hybrids significantly affect composition, physical and processing properties of sorghums. White tan sorghum (WT) hybrids were harder, more dense, and lighter in color than white purple (WP) hybrids or red hybrids. WP hybrids were more adversely affected by weathering and molds than WT hybrids. All of the ATx635 hybrids had significantly improved physical properties and higher milling yields than the other white hybrids. This grain has a thin pericarp particularly suited to whole grain extrusion.

Networking Activities

Southern Africa

INTSORMIL interaction with Professor Taylor and his colleagues at the University of Pretoria informed many future African food industry leaders of the potential role of sorghum and millets as food and industrial ingredients. Three Ph.D. students graduated and returned to Mozambique, Ethiopia and Zimbabwe.

Martin Kebakile (Ph.D. student, Botswana), Stephen Barrion and Luke Mugode (M.S. students), Food Science Department, University of Pretoria, continued their studies with partial support from INTSORMIL. Workshops were held to demonstrate the use of sorghums in food and feeds for Southern Africa.

Sorghum use in decorticated meals for porridges is increasing in spite of a 14% value-added tax on sorghum in South Africa. The currently strong interest in white sorghums by South African breweries has stimulated interest in improved sorghum cultivars for Southern Africa.

Professor Taylor's research program is optimizing processes using local equipment for sorghum and millet. For example, Mr. Kebakile compared traditional and modern dry milling methods for 10 varieties of sorghum which suggests a roller mill was summarized in *Cereal Foods World* in 2007. Mr. Barrion, University of Namibia, is completing a M.S. on milling of pearl millet and its food quality. Mr. Mugode's work on sorghum brewing in Zambia continues.

Dr. Leda Hugo, Head, Agronomy Department, Eduardo Mondlane University, Mozambique, received her Ph.D. from University of Pretoria with partial support from INTSORMIL.

Central America, Mexico and South America

Sorghum starch, malting and brewing studies. Dr. S.O. Serna-Saldivar, ITESM, Monterrey, Mexico, is continuing to collaborate on sorghum research, especially with graduate students working on sorghum for brewing and healthy foods, i.e., anticancer activities. Dr. Serna-Saldivar has provided assistance to our projects in El Salvador and Nicaragua, and was a key speaker in the Nicaraguan white sorghum utilization workshop.

Dr. L.W. Rooney made several trips to El Salvador, Nicaragua and Mexico to develop collaborative research plans and to participate in workshops on utilization of sorghum for human and animals which were jointly sponsored by CENTA, INTA, AM-PROCESSORS and INTSORMIL. Myths about sorghum tannins were discussed. We graduated five graduate students from Central America and Mexico who were partially funded on TAM-226. Ms. Vilma Ruth Calderon, Food Technologist, CENTA, will return to El Salvador in September 2007 with her M.S. degree. We hosted three EAP, Zamorano, Honduras food science visiting scholars for the spring semester of 2005-2007.

West Africa

Ms. Yara Koreissi, Food Scientist, IER, Mali, and Mr. Joseph Gayin, Assistant Research Scientist and Borlaug Fellow, Food Research Institute, CSIR, Accra, Ghana, received short-term training in our laboratory. Lloyd Rooney participated in workshops in Mali and Senegal on marketing of sorghum and millet feed and food products.

North America

Numerous papers were presented at the American Association of Cereal Chemists conferences (37), the Institute of Food

Technologists conferences (8), commercial food companies and to other groups. For example, a special seminar and demonstrations of gluten-free products from white sorghum was presented to 52 Disney World chefs.

More than 255 participants from all over the world enrolled in the annual 1-week short course on practical snack food production for private industry in which sorghum utilization was part of the program. A book, *Snack Foods Processing*, co-edited by Lloyd Rooney, contained information on food sorghum.

Training, Education and Human Resource Development

Eleven M.S. degree and four Ph.D. students graduated; nine visiting scholars were provided short-term training. Our collaboration with Dr. Serna-Saldivar, Head, Food Science Dept., ITESM, Monterrey, Mexico has led to completion of six or more M.S. degrees. These scientists have positions in the Mexican food industry which transfers technology directly to industry.

Collaboration with University of Pretoria has educated three Ph.D. students, and one Ph.D. and two M.S. students continue.

Publications and Presentations

(In 6 years, 127 publications, excluding proceedings: 29 journal articles, 10 book chapters, 10 theses, 1 non-thesis opt, 4 dissertations, 73 abstracts)

Journal Articles

- Dykes, L. and L.W. Rooney. 2007. Phenolic compounds in cereal grains and their health benefits. *Cereal Foods World* 52:105-111.
- Kebakile, M.M., L.W. Rooney, and J.R.N. Taylor. 2007. Effects of hand pounding, abrasive decortication-hammer milling, roller milling, and sorghum type on sorghum meal extraction and quality. *Cereal Foods World* 52:129-137.
- Dykes, L. and L.W. Rooney. 2006. Sorghum and millet phenols and antioxidants. *J. of Cereal Science* 44:236-251.
- Rodriguez-Herrera, R., R.D. Waniska, W.L. Rooney, C.N. Aguilar, and J.C. Contreras-Esquivel. 2006. Antifungal Proteins during Sorghum Grain Development and Grain Mold Resistance. *J. Phytopathology* 154:565-571.

Books, Book Chapters and Proceedings

- Rooney, L.W. 2007. Mycotoxins in grains. *Supply Chain Management of Millets for Processing into Feeds and Foods*, Dakar, Senegal, May 16, 2007, Dakar, Senegal.
- Rooney, L.W. 2006. Phenols, antioxidants and bioactives of sorghum food. *Brazilian National Corn and Sorghum Conference*, August 30, Belo Horizonte, Brazil.
- Rooney, L.W. 2006. Sorghum and nutraceutical food applications. *American Seed Trade Association (ASTA) 61st Corn, Sorghum and Soybean Seed Research Conference*, December 6-8, Chicago, IL.

Dissertations and Theses

- Barron, M.E. May 2007. MS Thesis. The effect of flaxseed hulls on expanded corn meal snacks. Texas A&M University, College Station, TX. 123 pp.
- Dlamini, N.R.N. May 2007. Effect of sorghum type and processing on the antioxidant properties of sorghum [*Sorghum bicolor* (L.) Moench] based foods. PhD Dissertation. Texas A&M University, College Station, Texas. 130 pp.
- Hines, L.W. May 2007. Development of specialty breads as nutraceutical products. MS Thesis. Texas A&M University, College Station, TX. 111 pp.

Abstracts

- Austin, D.L., L.W. Rooney, and C.M. McDonough. 2007. The effects of sorghum bran substitution and whole grain flours on starch digestibility and Estimated Glycemic Index (EGI) of porridges. Texas A&M University Student Research Week, College Station, TX.
- Calderon, V.R., L.W. Rooney, C.M. McDonough. 2007. Developing quick methods to cook sorghum for different food applications. Texas A&M University Student Research Week, College Station, TX.
- Calderon, V. 2007. Sorghum cooking quality and effect of pretreatment on physical properties of sorghum kernels. (Spanish ppt) Program Cooperativo CentroAmerica de Cultivos y Animales (PCCMCA), Guatemala City.
- Cardenas-Hinojosa, A.P., D. Guajardo-Flores, L. Dykes, C.M. McDonough, and L.W. Rooney. 2007. Analysis of phenols, tannins, and antioxidant activity of grain legumes compared with different whole grain cereals. Texas A&M University Student Research Week, College Station, TX.
- Guajardo-Flores, D., A.P. Cardenas-Hinojosa, L. Dykes, C.M. McDonough, and L.W. Rooney. 2007. Comparison of total phenol, antioxidant activity and tannin content in different grains. Texas A&M University Student Research Week, College Station, TX.
- Austin, D.L., L.W. Rooney, and C.M. McDonough. 2006. The effect of cooking on starch digestibility of corn and sorghum porridges. American Association of Cereal Chemists (AACC), San Francisco, CA, <http://www.wgsummit.org/program/posters.cfm #212>
- Calderón, V.R., L. Sandoval, L.W. Rooney, and S. Mason. 2006. Grain quality analysis of sorghum samples from El Salvador. American Association of Cereal Chemists (AACC), San Francisco, CA, <http://www.wgsummit.org/program/posters.cfm #304>
- Calderon, V.R., L.W. Rooney, C.M. McDonough. 2006. Developing quick methods to cook sorghum for different food applications. American Association of Cereal Chemists (AACC), San Francisco, CA, <http://www.wgsummit.org/program/posters.cfm #295>
- Cardenas-Hinojosa, A.P., D. Guajardo-Flores, L. Dykes, C.M. McDonough, and L.W. Rooney. 2006. Analysis of phenols, tannins, and antioxidant activity of grain legumes compared with different whole grain cereals. American Association of Cereal Chemists (AACC), San Francisco, CA, <http://www.wgsummit.org/program/posters.cfm #224>
- Dlamini, N.R., J.R.N. Taylor, C.M. McDonough, L. Dykes, and L.W. Rooney. 2006. Procyanidins in processed sorghum-based food products. American Association of Cereal Chemists (AACC), San Francisco, CA, <http://www.wgsummit.org/program/posters.cfm #211>
- Dykes, L. and L.W. Rooney. 2006. Comparison of total phenol and antioxidant activity levels of lemon-yellow and red pericarp sorghums. American Association of Cereal Chemists (AACC), San Francisco, CA, <http://www.wgsummit.org/program/posters.cfm #274>
- Guajardo-Flores, D., A.P. Cardenas-Hinojosa, L. Dykes, C.M. McDonough, and L.W. Rooney. 2006. Comparison of total phenol, antioxidant activity and tannin content in different grains. American Association of Cereal Chemists (AACC), San Francisco, CA, <http://www.wgsummit.org/program/posters.cfm #231>
- McDonough, C.M., L. Dykes, R.J. Carroll, L.W. Rooney, and N.D. Turner. 2006. Antioxidant activity in sorghum bran diets and their effect on colon carcinogenesis. American Association of Cereal Chemists (AACC), San Francisco, CA, <http://www.wgsummit.org/program/posters.cfm #271>

Entrepreneurship and Product Development in East Africa: A Strategy to Promote Increased Use of Sorghum and Millet

Project UNL 220

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Summary

Since this project's inception in March 2005, we have established, primarily in Tanzania, an active educational and small-business assistance infrastructure designed to support entrepreneurial businesses developing sorghum and millet food products. This assistance program has provided information to over 140 business groups and farmers. The program uses a model from the University of Nebraska's Food Processing Center. The Food Processing Center model is based on the realization that for food businesses to be successful there must be a strong linkage between services provided in business, marketing, supply chain management, and the technological/scientific aspects of foods. The assistance program involves: (i) training current or potential food processors starting and running a sorghum and pearl millet based business, (ii) practical hands-on training on how to process/prepare different sorghum-based food products, (iii) a one-on-one follow up of every processor at their place of work. During the project period our clients have developed a wide range of sorghum and millet-based food products, including: weaning foods, sorghum flours, popped sorghum, porridges, composite flours, sorghum breads, rolls, cakes, chapatti, pilau, and hospital-grade nutrient flour mixes. In addition, several businesses and women's groups now offer dehulling and sorghum/millet grinding services available to entire towns. Farmer training has focused on grain quality, cleaning, and storage techniques to achieve high-quality marketable grain for food and industrial uses.

- Farmers have an established outlet for cash sales of high-quality sorghum and millet.
- Small businesses or cooperatives develop processing capabilities enabling the incorporation of sorghum and millet into a wide variety of food products.
- Markets and market channels for sorghum and millet-based products develop.

Further develop research, extension and marketing expertise of National Agricultural Research program scientists and professionals so that they can:

- Offer business and technical assistance to processors and small businesses in order to speed development of sorghum and millet food products.
- Advise producers on which grain type(s) are ideally suited for particular processors, including both very small entrepreneurs, regional-village level millers, and larger multinational brewers (among others).

Research Findings and Project Output

Representative clients were impacted as noted below:

Note: Not all clients or project types are listed; multiple similar situations are omitted.

Objectives, Production and Utilization Constraints

Long Term Program Objectives

Development of successful entrepreneurial businesses that adds value to sorghum and millet such that:

Initial Client Status

- Producing weaning food without using sorghum
- Was not using sorghum (was using other cereals) in formulation of nutritious flour (*Lishe*).

Processed per month:

- 100 kg per month of *Lishe* flour using other cereals but was interested in processing sorghum
- 100 pieces of bread (made without sorghum) per week
- Processes 40 kg of *Lishe* per month without sorghum
- Processes about 15 kg of soya per month
- Processes 10 kg of Soya and *Lishe* per month respectively
- Processes 4 kg of sorghum per month
- Processes 60 bottles of jam per month
- Processes about 20 kg of sorghum per month for mixing in *Lishe*
- Processes 50 kg, 20 kg and 30 kg of *Lishe*, soya and finger millet per month respectively.
- Processes 200 kg of *Lishe* using other cereals, and 30 kg of sorghum per month

Current Status as of May 2007

- Tested different sorghum based weaning food formulations
- Received on site assistance with food development
- Developed different sorghum processed products (sorghum flour and popped sorghum)
- Project team assisted in developing simple packages and labels
- Received on site assistance with food development and labeling.
- Producing and packaging popped sorghum.
- Secured orders for sorghum based foods (cakes, flour and bread)
- Has opened her own vending shop.
- Processes 60 kg of sorghum per month for *lishe*, cakes, flour and bread (in addition to 100 kg of other flours).
- Provides sorghum porridge to construction workers who are working near her office.
- Processing about 100 kg of sorghum flour per month
- Produces 3 different sorghum products i.e. sorghum flour, sorghum bites and sorghum based composite flours.
- Developed a bankable business plan for sorghum based products
- Trained 3 other womens groups (of approximately 10 members each) on processing different sorghum products.
- Producing 10 kg of popped-sorghum for primary school children
- Processes about 80 kg of sorghum flour per month
- Has incorporated sorghum in all her processed *lishe* flour.
- Developed a bankable business plan for sorghum based products
- From knowledge gained during the workshop they are now commercially cooking sorghum *Pilau* and selling popped sorghum
- Processing sorghum buns (*maandazi*) for school pupils
- Processed about 200 kg of sorghum that is included in different sorghum products (buns, sorghum flour, *chapatti*, *pilau*, and *lishe*).
- Has opened their own vending shop near Yombo Vituka primary school
- They have registered their group as partnership business.
- Processed 90 kg of pearl millet per month and is selling it to people with special food requirements (diabetics)
- Has trained more than 55 farmers on processing different sorghum and pearl millet products
- Is selling pearl millet flour to women who cook morning porridge for street vendors
- Processing 350 kg of sorghum per month
- Trained more than 8 processor groups (of approximately 15 members each) in Dar es Salaam and Mtwara region

Initial Client Status

- Producing *Lishe* flour and using about 5kg of sorghum per month.
- Had used sorghum on trial basis
- Just started processing food products after graduation from Sokoine University of Agriculture (SUA).
- Processed 150 kg of Lishe per month without using sorghum
- Has a mini processing factory TOTOMIX with maize dehuller, dryers, and grain silos and milling machines.
- Process nutritious foods targeting people leaving with HIV/AIDS
- Miller (milling only maize)
- Supplies Dodoma prisons with maize flour

Current Status as of May 2007

- Trained about 150 sorghum farmers in Mtwara region
- Produced 6 different sorghum products (sorghum flour, sorghum based composite flour, buns, bread, cakes and *chapatti*)
- Developed a bankable business plan for sorghum based products
- Attended different trade fairs in Tanzania, Uganda and Kenya
- Their dehulling machine has dehulled sorghum from more than 1,000 households located in their Mbagala division. Also they supplied dehulled sorghum to other processors located in Dar es Saalam.
- Processing about 120 kg of sorghum based flour per month
- Processed 3 sorghum based products (sorghum flour and sorghum based composite flour '*lishe*') and cake.
- Secured orders from local super markets for sorghum flour and sorghum cake.
- Processing about 60 kg of sorghum per month.
- Processes sorghum flour and sorghum based composite flour and supplies the flours to local shops.
- Contacts with sorghum farmers for her grain.
- Processing 150 kg of sorghum per month.
- He has specialized in incorporating sorghum in his composite flour.
- Processing about 400 Kg of sorghum for his Lishe formulation "TOTOMIX".
- Supplies Turiani Hospital child feeding program with sorghum based Lishe
- Supplies local markets with sorghum based products
- Developed packaging and label with assistance from project staff at SUA.
- Operating a sorghum dehulling machine which serves more than 2,500 households in Bwagala village.
- Processing about 150 kg of sorghum per month
- Produced 2 different sorghum products (sorghum flour and sorghum based composite flour and)
- Developed a bankable business plan for sorghum based products
- Serves orphans living in their orphanage centre with sorghum based products
- The have received orders of sorghum flour from other missionary charity organizations in Dodoma
- Secured a loan from CRDB bank to establish a medium scale sorghum processing milling machine.
- He has ordered industrial scale dehulling and milling machine with high capacity from South Africa
- He is expecting to open his small processing industry in the near future

Initial Client Status

- Produces nutritional flour without sorghum.
- Supplies international CARE program with *Lishe*
- Mills maize flour but showed interest in starting to mill sorghum and sell flour to consumers around the village.
- Co-ordinate diocese of central Tanganyika feeding programme under CARE international
- Produces wheat based breads (600-700 loaves a day).

Current Status as of May 2007

- Operating 6.6 HP Improved disc sorghum dehulling machine which serve more than 3,000 households in area D, Dodoma region.
- Processing 350 kg of sorghum per month
- Producing 3 different sorghum products (sorghum flour, sorghum based composite flour and *chapatti*)
- Developed a bankable business plan for sorghum based products
- Involved in dehulling sorghum to about 500 sorghum consumer and processors
- Trained more than 50 farmers on utilization of sorghum through processing different sorghum products i.e. sorghum flour, incorporation of sorghum in composite flour, cooking of *pilau*, cakes, buns and *chapatti*
- Now producing in excess of 1,000 loaves a day, using a 80% wheat and 20% sorghum flour mixture in Dar es Salaam.

Description of Methods of Work Used

The project uses a systematic procedure for assisting clients. Clients interested in using sorghum or millet in food products for their existing business or those wishing to start new entrepreneurial businesses, attend a 1-day workshop focusing on the basics of creating and marketing food products in East Africa. These workshops have been held in three regions within Tanzania. The workshop content was made specific to East Africa by translating and adapting educational materials created at the University of Nebraska. After attending the first workshop, smaller processors attend a second (hands-on) workshop that focuses on practical uses of sorghum and millet in food products, and the limitations these ingredients have for certain uses. Clients wishing to continue (and those with existing businesses) receive direct one-to-one

assistance in product / process or market development assistance from Food Science & Technology staff at Sokoine University of Agriculture. In certain cases, Women's Groups that have attended the workshop series have gone on to train their own clients and/or other villagers on basic sorghum-food processing and milling techniques. SUA scientists have also facilitated the availability of higher quality sorghum and millet grain by conducting farmer training workshops that focus on appropriate sorghum/millet grain handling techniques.

