Crop Utilization and Marketing

Enhancing the Utilization and Marketability of Sorghum and Pearl Millet through Improvement in Grain Quality, Processing, Procedures, and Technology Transfer to the Poultry Industry

Projects KSU 102
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Introduction and Justification

Throughout human history, as economies have grown and people have experienced greater wealth, consumption of animal products has increased. Poultry production is particularly well suited to a rapidly growing demand for animal products because of relatively low expenditures for facilities, equipment, and land area to enter into the industry. Additionally, the short production cycle (less than two months of age at slaughter for a broiler vs six months for a pig vs 18 months for a feedlot steer) and extreme efficiency of growth (feed to gain ratios of about two in a broiler vs three in a pigs to six in a feedlot steer) make poultry attractive to growers that need minimal input of capital and rapid return on their investment. There are several beneficial aspects to the phenomenon of explosive growth in global production of poultry, especially in developing regions such as West Africa. These benefits include (but are not limited to) diversification of farm enterprises to include animal production in addition to crops, development of alternative/stable markets for cereal grains, and transition of cereal production from a subsistence activity to a cash crop (when sold to livestock producers) that yields disposable household income. Even more important are the contributions of a healthy livestock feeding sector to the nutritional status of humans that consume the resulting animal products and to a general increase in quality of life. Sorghum and millet do indeed have the potential, via their hardiness and drought tolerance, to bring the prosperity associated with animal agriculture into regions of the world that crops such as maize cannot. Thus it is our objective to ensure that sorghum and millet enjoy a prominent position in the development of animal agriculture in West Africa.

Our overall strategy for this project has been to assemble a team of U.S. and host country collaborators to focus on educational and promotional programs to ensure expanded use of sorghum as animal feed and research activities to ensure improvements in sorghum grain quality. We have worked, are working, and will continue to work to integrate research projects involving pathology/grain weathering, breeding for improved nutritional value, feed processing, and poultry nutrition/production. Specifically for the 2007-2008 fiscal year, we were able to complete a truly regional project involving a common protocol replicated in Senegal, Mali, Burkina Faso, Niger, and Nigeria. The objective of this project was to compare maize to locally produced sorghum grain that had been properly milled and, of equal importance, to develop a net-

work of collaborating poultry scientists in this part of the world. Salissou Issa (Ph.D. student at Kansas State) spent the summer in West Africa visiting each experiment station to deliver feed ingredients and initiate the growth assays. As of this last month, all data have been submitted to Kansas State University and we are in the process of statistical analyses of those data. Additionally, we were able to complete a similar experiment with our collaborators in Nicaragua and those prize-winning data were presented by Carolina Feoli (Ph.D. student at Kansas State) at the PCCMCA in Costa Rica. Additional accomplishments included completion of a M.S. thesis on sorghum tannins by Cynthia Monge, numerous presentations by these three students at various professional meetings, and Dr. Hancock being invited to serve on the Scientific Committee as Chair of the Nutrition Section of the International Conference for the Improved Competitiveness of Poultry Production in Africa held in conjunction with the 40th Anniversary of the School of Veterinary Medicine, E.I.S.M.V. de Dakar.

Objectives and Implementation Sites

Our efforts to expand use of sorghum grain and millet as animal feed necessitated integration of knowledge gained from researchers in pathology, breeding, agronomy, pest management, and economics as follows:

1. We were able to work with plant breeders (e.g., Clara, Tuinstra, and Rooney) in El Salvador, Kansas/Indiana, and Texas to identify genetic materials with superior agronomic and nutritional merit that will be used in feeding experiments conducted in Kansas during the next fiscal year.
2. The input of cereal chemists (e.g., Ndoye, Nkama, Rooney, and Bean) in West Africa, Texas, and USDA/Kansas were used to identify seed characteristics (endosperm type/texture/chemistry, tannin type and concentration, and molds/mycotoxins) deemed of value for the sorghums fed to broiler chicks in our just-completed regional project.
3. The expertise of economists (e.g., Abdoulaye and Sanders) in West Africa and Indiana was solicited to facilitate discussion of economic constraints on the poultry industry in West Africa during the International Conference for the Improved Competitiveness of Poultry Production in Africa that was held in Senegal.
4. Collaboration with grain scientists (e.g., McKinney and Behnke) in the Feed Science Program at Kansas State University was used to establish best manufacturing practices for diets used in our experiments in West Africa and Nicaragua.
5. Interaction with animal nutritionists (e.g., Issa, Traore, Hien, Sangare, Missohou, Rios, and Campabadahl) in West Africa, Central America, and Kansas was essential to diet formulation strategies and conduct of our chick-feeding experiments.

Specific sites targeted for our 2007-2008 activities included regional research institutes in West Africa, the Agricultural University of Nicaragua and, of course, continuation of our research activities on campus here at Kansas State University.

Research Methodology and Strategy

Active participation of host country scientists was a core component of our project during the 2007-2008 fiscal year. Beginning with participation by Issa in the INTSORMIL Regional Planning meeting held in Bamako, our goal was to meet as many collaborators as possible and especially those that were not part of previous INTSORMIL activities. Issa visited with potential collaborators form Burkina Faso, Mali, Niger, Senegal, and Nigeria to formulate a common protocol for an experiment to address a region-wide concern among poultry producers as it relates to the use of sorghum grain. Also, Hancock used his time at the Poultry Conference in Senegal to network with many of these same collaborators and to finalize a common protocol. As for the Americas, Feoli garnered inputs from Francisco Vargus (of AMPROSOR, the National Sorghum Producers Association of Nicaragua) and Miguel Rios (at UNA) in regard to our second demonstration project at UNA in Managua. Finally, at Kansas State University Monge finished an M.S. degree resulting from her thesis efforts with sorghum tannins in close collaboration with Tuinstra, Bean, and Rooney.

Research Results

Specifically for the 2007-2008 fiscal year, we were able to complete a truly regional project involving a common protocol replicated in Senegal (on-site supervisor was Dr. Ayao Missohou, Veterinary Medicine and Animal Nutrition, Department of Biological Sciences, School of Veterinary Medicine, Université Cheikh Anta Diop, Dakar), Mali (on-site supervisor was Dr. Bantieni Traore, Animal Nutrition and Production, Centre Régional de la Recherche Agronomique de Sotuba, Bamako), Burkina Faso (on-site coordinator was Dr. Ollo Hien, Nutrition and Production, Institut de l'Environnement et de Recherches Agricoles, Bobo-Dioulasso), Niger (on-site supervisor was Dr. Salissou Issa, Animal Nutrition and Husbandry, INRAN Rainfed Crops Program, Niamey), and Nigeria (on-site supervisor was Dr. Iro Nkama, Food Science and Cereal Chemistry, University of Maiduguri). Issa spend the summer in West Africa visiting each experiment station to deliver feed ingredients and initiate the growth assays. The objective of this project was to compare maize to locally produced sorghum grain that had been properly milled. For the experiment, 400 1-day-old broiler chicks were randomly allocated to 16 pens (4 treatments and 4 pens/treatment with 25 birds/pen). This allocation was repeated at 5 sites for a total of 2,000 birds used in the experiment. The control diet was corn-based with fishmeal, peanut meal, cotton seed meal, and soy bean meal as the primary protein supplements. Sorghum was used to replace the corn on a wt/wt basis so that treatments were corn- vs sorghum-based diets with the cereals ground through a 6.4 mm vs 2 mm screen. The birds were allowed to consume feed and water on an ad-libitum basis for 42 days with weights taken on day 0, 21, and 42. At the end of the experiment, 12 birds/pen were killed for carcass evaluation. Carcass measurements included weights of the live bird, carcass, gizzard, liver, mesenteric fat, and full/empty intestines. Additionally, gizzards were scored for lesions on a scale of 0 to 5. All data have been submitted to Kansas State University and we are in the process of pooling the data for statistical analyses with hopes of generating a presentation for the Poultry Science Meetings this next summer. This project will serve as the core of Issa's Ph.D. dissertation.

As for the Central America activities, we were able to complete an experiment with our collaborators in Nicaragua (Miguel Rios and Francisco Vargas). Four hundred sixty eight 2-day-old broiler chicks were used in a 14-day growth assay to determine

the nutritional value of imported corn (US no. 2 with 7.7% CP and 3.6% crude fat) vs locally produced bronze (CB-8996, a hybrid with 7.9% CP and 2.5% crude fat) and white (Pinolero-1, a variety with 6.7% CP and 2.5% crude fat) sorghum grain. The chicks were allotted to pens with 26 birds/pen and 6 pens/treatment. Feed and water were consumed on an ad libitum basis. The corn and sorghums were ground through a hammermill (4-mm screen openings) and blended into diets that were formulated to 1.29% Lys, 0.99% Met+Cys, 1.1% Ca, and 0.49% available P. All data were analyzed as a randomized complete block with location within the barn as the blocking term and initial weight as a covariate. Orthogonal contrasts were used to separate treatment means with comparisons of corn vs the sorghums and bronze sorghum vs white sorghum. There was no effect of grain source on average daily gain. However, average daily feed intake was greater and gain to feed ratio was lower for chicks fed the corn-based diet compared to those fed the sorghum-based diets. There were no differences in rate of gain or food intake among chicks fed the two sorghums, but those fed white sorghum tended to have greater gain to feed ratio. For the diets with corn, bronze sorghum, and white sorghum, average daily gain was 24.7, 25.2, and 25.9 g/d, average daily feed intake was 48.5, 45.2, and 43.7 g/d, and gain to feed ratio was 509, 558, and 593 g/kg, respectively. In conclusion, bronze and white sorghums produced in Nicaragua supported equal or greater growth performance compared to imported corn when fed to broiler chicks.

As for the thesis work of Monge, 3 experiments were conducted to determine the effects of tannins on the nutritional value of sorghum grain in broiler chicks. In Exp 1, there was an 8% decrease in rate of gain and a trend for decreased gain:feed ratio as tannin in the sorghum was increased from none to 5.44% CE. The trend in gain:feed was consistent with quadratic responses in percentage retention of DM, N, and GE with concentration of tannins greater than 1.36% CE resulting in decrease nutrient utilization. In Exp 2, birds fed pericarp from tannin sorghum (Sumac) had less ADG and retention of DM, N, and GE with decreases of 8, 11, 8, and 6%, respectively, compared to birds fed diets with pericarp from a non-tannin sorghum (Mycogen). In Exp 3, birds were fed bran from three different tannin sorghums at the same catechin concentration (0.6 mg CE/g DM) to test the potency of tannins from different sources. When compared to birds fed pericarp from non-tannin sorghum (Mycogen), birds fed tannin sorghums had less rate of gain and MEn, but there was little evidence to suggest major differences in potency of the tannins from different sorghums.

Our overall objective and expected outcome for this project is to ensure that sorghum is a preferred cereal grain for poultry feeding. In the semiarid to arid environments of West Africa and the Central Great Plains of the U.S., such acceptance and recognition will go far to improve the marketability of sorghum. Enhanced marketing opportunities should result in more favorable pricing with stable income for grain producers and processors. Results such as those we have generated thus far should go far to make an argument for sorghum as a preferred feedstuff in diets for livestock. Our next steps will be to continue such research activities and emphasize transfer of our findings to livestock producers and feed manufacturers that will use the sorghum grain produced by crop farmers.

Networking Activities

Our networking activities have been extensive during the 2007-2008 fiscal year with the efforts of Issa to accomplish a regional feeding project in West Africa as prime example. Beginning with his efforts at the INTSORMIL Regional Planning Meeting in Bamako, to his physical oversight of that project, to his presentation at the Southeast Poultry and Egg Expo in Atlanta (the largest poultry expo on the planet), Issa has been instrumental in or networking activities. Feoli has been the principal component of our networking activities in Central America with physical oversight of our feeding experiments in Nicaragua. Additionally, she has been active at professional meetings with presentations at the Poultry Science Meetings in Niagara Falls, the PCCMCA Meetings in Central America, and the CLANA Meetings in Mexico. Hancock also has been active in promoting sorghum with presentations and seminars given around the globe (e.g., China, Russia, Ireland, England, Denmark, Holland, Germany, France, Italy, Spain, Portugal, Colombia, El Salvador, Honduras, Nicaragua, and Costa Rica) and serving on the Scientific Committee as Chair of the Nutrition Section of the International Conference for the Improved Competitiveness of Poultry Production in Africa (held in conjunction with the 40th Anniversary of the School of Veterinary Medicine, E.I.S.M.V. de Dakar, Senegal).

Publications and Presentations

Feoli, C., J.D. Hancock, M.G. Viscarra, R. Rodríguez, M.J. Ríos, F.J. Baltodano, F. Vargas, and S.C. Mason. 2008. Nutritional value of imported corn versus locally produced bronze and white sorghum grain when fed to broiler chicks in Nicaragua. Presented at the 64th Annual Meeting of the PCCMCA, San Jose, Costa Rica (April 14-18) and the Annual Poultry Science Association Meetings, Niagara Falls (July 21-23).

Hancock, J.D. 2008. Sorghum Utilization – Animal Diets. Great Plains Sorghum Conference, Manhattan, KS, September 3-4.

Hancock, J.D. 2008. Nutritional consequences of feedstuff selection and feed manufacturing practices. RAPCO (Cursos Regionales en Produccion Animal) Short Course in Feed Manufacturing, Atenas, Costa Rica (July 28-August 1) and Antioquia, Colombia (August 3-8).

Hancock, J.D. 2008. Nutritional Strategies for Production of Poultry in the Sub-Saharan Environments of Africa. International Conference for the Improved Competitiveness of Poultry Production in Africa, 40th Anniversary of the School of Veterinary Medicine, Dakar, Senegal, May 5-9.

Hancock, J.D. 2008. Merits and constraints for the expanded use of sorghum grain in animal feeding. The U.S. Grains Council Seminar Series for Western Europe with presentations in Ireland, England, Holland, and France (February 16-24), and Denmark, Italy, Spain, and Portugal (September 13-23).

Hancock, J.D. 2007. Merits of forage and grain sorghums in diets for livestock feeding. A presentation to the technical staff of PROLECHE (the National Dairy Association), San Salvador, El Salvador, December 7.

Hancock, J.D. 2007. Current concepts for the use of sorghum grain to reduce cost of gain in poultry. A presentation to the technical staff and Board of Directors for AVES (the National Poultry Growers Association), San Salvador, El Salvador, December 6.

Hancock, J.D. 2007. Diet formulation and milling strategies to maximize the nutritional value of sorghum-based diets for livestock feeding. The Ag Expo (i.e., State Fair) of Choluteca, Choluteca, Honduras, December 5.

Hancock, J.D. 2007. Effects of particle size of imported corn and domestically produced sorghums on growth performance in broiler chicks: A collaborative efforts among KSU, INTSORMIL, UNA, and ANPROSOR. Presented to the Board of Directors for ANPROSOR, Managua, Nicaragua, December 2.

Issa, S., J.D. Hancock, M.R. Tuinstra, I. Kapran, and S. Kaka. 2008. Effects of sorghum variety on growth and carcass characteristics in broiler chicks reared in West Africa. Presented at the International Poultry Scientific Forum, Atlanta GA, January 21-22.

Monge, C.R. 2008. Effects of Tannins on the Nutritional Value of Sorghum Grain in Broiler Chicks. M.S. Thesis, Kansas State University, Manhattan.

Market Development in Support of Sorghum and Millet Farmers in Tanzania and Zambia

Project OSU 101
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Introduction and Justification

Improving the income and food security of small-scale sorghum and millet farmers in Zambia and Tanzania through the identification of new market opportunities and related constraints in the supply chain is the focus of this INTSORMIL/CRSP project. Sorghum and millet are traditional food staples and are important producer and consumer goods in Tanzania and Zambia. In both countries, the productivity and profitability of these crops is low and so is the income of small farmers who produce them. A huge challenge facing these countries is to increase the productivity and incomes of small farmers to improve food security and to accelerate economic growth and prosperity in rural and urban areas. Improving technology and linking producers to markets are important parts of the solution to the problem (USAID Agriculture Strategy, 2004). Improving production and marketing technology will lead to greater productivity and higher incomes for sorghum and millet producers and lower food costs for consumers.

The major achievements in the past year were completion of the project activities as specified in the work plan for Tanzania and Zambia. These included (1) studies of technology adoption in both countries in the low potential areas surveyed in year one of the project, (2) conducting baseline farm household surveys in high potential areas, (3) studies of sorghum-based clear beer supply chain, (4) initiating the collection of information on seasonal price variability, and (5) selecting a student from Tanzania and Zambia for M.S. study at The OSU, beginning Autumn term 2008 and a PhD student from Zambia to begin study in the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) agricultural economics program at Bunda College in Malawi. The project also supported two M.S. students in agricultural economics at SUA and two senior research projects at UNZA.

The combined studies are designed to identify new and/or rapidly growing markets for sorghum and millet in value added processing for clear beer, food, and feed concentrate markets. These value added processors offer opportunities for smallholders to sell their crops to more secure and stable markets than those currently available. Improved linkages to these markets will enable smallholders to adopt improved technology to increase yields, production, and incomes. The baseline farm household surveys completed in 2008 in the high potential areas and those farm household surveys completed previously in the low potential areas are designed to establish the benchmarks and indicators for yields, production, incomes, and amounts processed in these new markets. The same households will be surveyed in the last year of the project to measure the amount by which the baseline indicators have increased during the life of the project.

Objectives and Implementation Sites

The INTSORMIL overall approach is to increase food security and promote market development of sorghum and pearl millet products. This is to be achieved by implementing the project specific goal of developing marketing strategies through a complementary applied marketing research program in Tanzania and Zambia.

These activities are centered on INTSORMIL project objectives one and seven: Objective 1: To facilitate the growth of rapidly expanding markets for sorghum and millet; Objective 7: To develop effective partnerships with national and international agencies engaged in the improvement of sorghum and pearl millet production and the betterment of people dependent on these crops for their livelihoods.

The project implementation sites are with collaborating universities and faculty located at Sokoine University of Agriculture (SUA) Morogoro, Tanzania and the University of Zambia (UNZA), School of Agriculture, Lusaka, Zambia.

Research Methodology and Strategy

The research activities described below focus on two sorghum and millet producing countries in East and Southern Africa: Tanzania and Zambia.

Studies of technology adoption: This study will be conducted in high and low potential production areas in Tanzania and Zambia. Baseline surveys already conducted will be augmented by follow-up baselines to measure adoption of technologies and to assess the impact of new market development on technological uptake. Household surveys conducted in low potential areas in both countries have been analyzed and manuscripts prepared on factors affecting adoption of recommended improved sorghum production technologies.

Household surveys have now been completed in high potential sorghum production areas in both countries and are currently being analyzed.

Sorghum-based clear beer studies: In both countries we are examining the entire supply chain for sorghum-based clear beer to identify ways to remove these constraints. Three important dimensions/features of the supply chain that are being analyzed are a sufficient, reliable, and quality supply of sorghum.

Seasonal price variability studies: Many times farmers are forced to sell their crops at harvest time when crop prices are frequently at the lowest level. Crop prices may increase substantially during the remainder of the marketing year. Studies of the monthly price changes, costs of storage and household seasonal cash flows have been initiated to identify ways for farmers to sell at higher prices in the post-harvest season.

Description of Interdisciplinary Team

This project is part of an INTSORMIL team of scientists from various disciplines that develop research and outreach program for sorghum, millet, and other grains. We maintain contact with several INTSORMIL researchers to identify opportunities for collaboration. The scientists include John Sanders (economist) at Purdue University, Gary Peterson, (plant breeding and Regional Program Coordinator for Southern Africa) at Texas A& M University, Charles Wortmann (soil scientist) and David Jackson (food scientist) at University of Nebraska, Gbisa Ejeta (plant breeding and Regional Program Coordinator for the Horn of Africa) at Purdue University, Medson Chisi (sorghum breeder) at the Golden Valley Research Station in Zambia; the sorghum research team at Ilonga Agricultural Research Institute, Kilosa, Tanzania; and the Entrepreneurship and Product Development Group at the University of Nebraska and Sokoine University of Agriculture, Tanzania.

Research Results

Tanzania

In Tanzania, the project activities for July 1, 2007 to September 29, 2008 were to: (1) examine technology adoption in the Dodoma region, (2) conduct baseline farm household interviews in a high potential area, (3) study the supply chain for sorghum-based clear beer, (4) initiate the collection of information on seasonal price variability, and (5) select a student from Tanzania for M.S. study at The OSU to beginning Autumn term 2008.

Adoption of Improved Production Technologies Among Smallholder Growers Of Maize and Sorghum

A draft manuscript on this topic has recently been completed that focuses on the Dodoma region. Empirical evidence from the study areas indicate that with respect to varieties grown, 63 % of respondents grew local varieties of maize and 37 % grew improved varieties. In contrast, 42 % of farmers grew local varieties of sorghum, and 59 % grew improved varieties. The improved varieties of sorghum that farmers used were Pato, Tegemeo, and Macia. Newly released sorghum varieties “Wahi” and “Hakika” were not being grown in the villages and many farmers were not aware of their existence. Results also indicate that the improved sorghum seed that farmers plant may not be the same quality as the seed first released to farmers. Sorghum farmers typically save seed from the current harvest for planting in the next crop year. This practice may continue for several years causing a decline in the genetic quality and productivity of the improved seed.

The analysis of tillage methods used indicates that the percentage of farmers in Dodoma-rural and Kongwa Districts who practiced no-tillage and conventional hand-hoe tillage were 64 percent and 77 percent for maize and sorghum, respectively. Conventional hand-hoe tillage practices are not well-suited to semi-arid areas because they do not conserve soil moisture. Deep tillage practices which conserve soil moisture more effectively were used by 37 percent and 23 percent of maize and sorghum farmers, respectively. In general, farmers appear slightly more willing to use deep tillage practices with maize than sorghum.

No respondent reported using inorganic fertilizers and herbicides. However, 28 and 13 percent of the farmers did apply manure on maize and sorghum, respectively. Mean manure application rates were approximately 0.14 and 0.63 tons/hectare for maize and sorghum, respectively. The low use of soil fertility supplements raises several concerns regarding the long term sustainability of farming without any attempts to enhance soil fertility and the benefits of using improved seed. Without fertilizers or manure, crop yields for most improved varieties will be low.

The most important factors explaining overall household adoption of improved maize and sorghum technologies are marital status, off-farm income, asset value and family labor. Adopters of improved technologies appear to have more resources including labor, income and capital. Adopters also appear to have larger farms; however, this variable was not significant perhaps because of limited variability among the observations. These results are consistent with the adoption literature, which indicates that adopters of new technologies have different household and farm characteristics than non-adopters and that farmer with more resources, both social and economic, are more apt to adopt new technologies. (Table 1)

Conduct Baseline Farm Household Interviews in a High Potential Area

A survey of high potential sorghum and millet production areas was completed to establish a baseline for households in high potential areas. Designation of high potential areas was completed in collaboration with host country scientists. The high potential

Table 1. Adoption of improved technology among smallholder growers of maize and sorghum, Dodoma Region, Tanzania, 2006.

Technologies	Maize	Sorghum
Seed		
- Local	63% adopted	42%
- Improved	37%	59%
Tillage		
- Traditional	64%	77%
- Deep tillage	36%	23%
Synthetic Fertilizer	0	0
Manure	28%	13%
- manure application rates	0.14 tons/ha	0.63 tons/ha

areas selected were Singida Rural and Simanjiro which are important sorghum areas linked to the clear beer processor, TBL brewery, in Arusha. The villages were selected based on the introduction of new sorghum varieties in Singida Rural (four villages) and the market linkages identified in Simanjiro (three villages). The survey sample size was 107 households: 59 from Singida Rural and 48 from Simanjiro.

Examine the Supply Chain for Sorghum-Based Clear Beer

The sorghum-based clear beer supply chain analysis is being conducted by Jeremia Makindara, a faculty member and Ph.D. candidate at SUA. The objective of the study is to assess the potential of producing sorghum-based clear beer value chain in Tanzania by mapping all the players along the chain, their roles and challenges they face. The farm survey is the initial stage in evaluating the supply chain of sorghum for commercial utilization. The sorghum value chain starts with smallholder producers who then sell their produce to village buyers. Some village buyers are agents of grain traders from urban centres who may sell produce to large scale industrial users such as Tanzania Breweries Limited (TBL) or Dar Brew Limited. Village buyers also sell to urban wholesalers. Some larger scale commercial sorghum farmers enter into contracts and sell directly to industrial users such as TBL or Dar Brew. Long term sustainability of a value chain depends upon potential demand of the buyers; consistent and high quality supplies from producers; as well as adequate transportation and storage infrastructure, profitability for all chain members, trust and contract enforcement mechanisms. In addition to the farm household interviews, interviews with traders (60), transporters (60), distributors and warehouse owners have been completed and are being tabulated.

Initiate the Collection of Information on Seasonal Price Variability

The project is collecting monthly price data to assess seasonal variability of sorghum and millet prices over the next four years (2008-2011). To initiate this process the Tanzanian collaborators at SUA developed a protocol for data collection to undertake the following:

1. Collect wholesale and retail prices for sorghum and millet in Dodoma and Singida (central Markets) on a weekly basis and;
2. Collect farm gate prices in the main sorghum and millet producing regions on a weekly basis.

Methodology

The contracted persons with support of SUA researchers from the Department of Agricultural Economics and Agribusiness (DAEA) are in charge of:

- Data collection process in respective regions
- The data are collected twice every week and are filled in a standard form translated into Swahili, which is appended over leaf
- Instruction for data collection are in the user-friendly form and the Lead consultants under DAEA demonstrated on how to fill the form
- DAEA shall collect these forms by the end of the year

Select a Student from Tanzania for M.S. Study at the OSU

The project is supporting M.S. degree study at OSU in agricultural economics for Joseph Mgaya from Tanzania who began his graduate study in autumn of 2008. OSU provides a cost share tuition award for this student.

Research Results

Zambia

In Zambia, the project activities for July 1, 2007 to September 29, 2008 were to: (1) examine technology adoption in the Siavonga area, (2) conduct baseline farm household interviews in a high potential area, (3) study the supply chain for clear beer, (4) initiate the collection of information on seasonal price variability, and (5) select a student from Zambia for M.S. study at The OSU to beginning Autumn term 2008 and select a student for the RUFORUM Ph.D. program located at Bunda College.

Adoption of Improved Technologies Among Smallholder Growers of Maize, Millet and Sorghum

A draft manuscript on this topic has recently been completed. This study used a household survey of smallholder farmers in sorghum and millet growing district (Siavonga area) to identify factors that influence adoption of improved technologies (improved seed, deep tillage, and manure/fertilizer) in the production of maize, millet and sorghum. Survey results from the study areas indicate that 40 % of respondents grew local varieties of maize and 60 % grew improved varieties. In contrast, 70 % of farmers grew local varieties of sorghum, and 30 % grew improved varieties. The improved varieties of sorghum that farmers used were Kuyuma and Sima and a few farmers reported planting the improved millet variety Lubasi.

The Tobit adoption model found differences among the key explanatory variables between adopters and non-adopters of improved technology. In addition to confirming that adopters are generally better off compared to non-adopters of improved technologies, the results indicate that some demographics (education, sex, marital status), farm size, wealth (as measured by the dwelling index, off-farm income), accessibility, and perception about the existence of production and marketing problems are important in explaining adoption in at least some of the crops. Besides the need to recognize the inherent heterogeneity among crops, broad-based investment in education, and marketing infrastructure and institutions could improve technology uptake. (Table 2)

Survey of Sorghum and Millet Farmers in Luanshya - A High Potential Area

A survey of sorghum and millet farmers in a high potential area was conducted in two blocks of Luanshya district north of Lusaka. Luanshya is a high potential sorghum producing area that also has market access advantages because of its close proximity (60 kilometers) to the Zambian Breweries Ndola facility that brews Eagle lager. Luanshya was selected after the researchers visited the Mumbwa area (the original high potential area selected) in June only to discover that very little sorghum is now grown there. Maize is the major crop now grown in the Mumbwa area. The change to maize is due in part to large government subsidies (60%) on maize seed and fertilizer prices. In the Luanshya survey, 170 households were visited, of which 164 were complete interviews. Data entry and cleaning has been completed. Progress toward indicators such as income growth, yield increases, and production increases will be measured against this baseline information in the high potential area. Sorghum breeders at the Golden Valley Research Station plan to introduce an improved sorghum variety (WP-13) to farmers in the area with assistance from CARE in 2008-09.

Sorghum-Based Clear Beer Supply Chain Study

The sorghum-based clear beer supply chain analysis is being conducted by Research Assistant, Bernadette Chimai and supervised by Dr. Gelson Tembo. A recent progress report has identified the value chain players, from farmers to retailers of the clear beer. Interviews were conducted with various representatives of firms that form part of the chain on their activities and experiences in the chain. The producer of Eagle lager, Zambian Breweries, was the first organization to be visited and was the primary source of information on the other chain players. Interviews were also conducted with CHC commodities, the sole supplier of sorghum to Zambian Breweries, and two of the official distributors of Eagle lager, R.S. Distributors and Nenima Trading. Various retailers within Lusaka were also visited.

In the work plan for 2008, the main activity outlined in the examination of the clear beer supply chain was the completion of interviews with retailers, wholesalers, brewers, warehouses, transporters, local buyers, farmers, and others. Information was required on supply chain players' operations, information flows, promotion flows, ownership flows, product flows, payment flows, constraints and the means for smallholders to sell in commercial markets. Estimates of future demand for the clear beer are planned to assess the growth potential of this market.

An interview conducted at CHC commodities, a grain trading company, with one of the employees yielded useful information on the flow of information on the quantities, quality and prices of sorghum required for production of clear beer as well as the ownership of the sorghum as it moves from the farmers' fields to Northern breweries. Further interviews are being conducted to collect actual prices of sorghum this year (including how they are determined) and how payments are made. Further interviews were also conducted with R.S Distributors on its operations and flow of clear beer from the brewers to the retailers. The main activity that remains to be done is the estimation of future demand for Eagle lager. We intend to estimate the future demand using sales/ production forecasts and trends in sales and production of the beer

Table 2. Adoption of improved technology among smallholder growers of maize and sorghum, Siavonga Region, Zambia, 2006.

Technologies	Maize	Sorghum
Seed		
- Local	40% adopted	70%
- Improved	60%	30%
Tillage		
- Traditional	46%	60%
- Deep tillage	45%	40%
Synthetic Fertilizer	0	0

since its introduction in 2005. Data will be obtained from Zambian Breweries in Lusaka. Currently efforts are being made to get interviews with the people authorized to provide the information.

Price Variability Study

Data collection has been completed. We collected monthly historical data from the Central Statistical Office (CSO) and the USAID FEWS NET project. The data have been re-organized and variables and values labeled in readiness for statistical analysis. A final-year student in the Department of Agricultural Economics and Extension Education, University of Zambia, has been spearheading this study and is using it as her thesis project.

Select a Student from Zambia for M.S. Study at the OSU and for Ph.D. at Ruforum

The project proposed M.S. degree study at OSU in agricultural economics for one student from Zambia. Bernadette Chimai, a recent UNZA graduate in agricultural economics, who was selected to begin her M.S. studies at OSU in autumn 2008 through the INTSORMIL project with a cost share from OSU. However, she had to postpone her plans because she is expecting a child. She, or possibly another candidate, is expected to begin studies at OSU in autumn of 2009.

Rebecca Lubinda, a faculty member in the Department of Agricultural Economics and Extension Education at UNZA, has decided to begin Ph.D. studies in agricultural economics this spring or next fall through the RUFORUM program located at Bunda College in Malawi. Her studies will be supported on a cost share basis between the INTSORMIL/Zambia project and the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM).

Networking Activities

The project maintains important linkages to the INTSORMIL program in Tanzania, Zambia, the U.S. and with the USAID Missions in each country. Contacts have been made with several INTSORMIL researchers to discuss collaboration. They include John Sanders (economist) at Purdue University, Gary Peterson, (plant breeding and Regional Program Coordinator for Southern Africa) at Texas A& M University, Charles Wortmann (soil scientist) and David Jackson (food scientist) at University of Nebraska, Gbisa Ejeta (plant breeding and Regional Program Coordinator for the Horn of Africa) at Purdue University, Medson Chisi (sorghum breeder) at the Golden Valley Research Station in Zambia, A.M. Mbwaga (sorghum breeder) at Ilonga Agricultural Research Institute, Kilosa, Tanzania; the Entrepreneurship and Product Development Group at the University of Nebraska and at SUA and at UNZA. An important linkage for training is the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM).

We presented a paper on preliminary research results and also networked in the INTSORMIL organized Horn of Africa (HOA) regional workshop held in Nairobi, Kenya in September, 2008. The workshop afforded an excellent opportunity to learn about the work of all the HOA researchers and the opportunities to further collaboration and to seek added funding.

Publications and Presentations

J. Mark Erbaugh, Donald W. Larson, Emmanuel R. Mbiha, Fredy T.M. Kilima, Gelson Tembo, and Priscilla Hamukwala. 2007. "An Evaluation of New Market Development and Marketing Strategies on Sorghum and Millet Farmers' Income in Tanzania and Zambia." INTSORMIL Annual Report. USAID/INTSORMIL Grant. University of Nebraska. Lincoln, Nebraska. Pp. 79-84.

J. Mark Erbaugh, Emmanuel R. Mbiha, Fredy T.M. Kilima, Jeremia Makindara, and Donald W. Larson. 2008. "Market Development in Support of Sorghum and Millet Farmers in Tanzania and Zambia." Presented at International Sorghum and Millet & Other Grains Meeting for PIs in the Horn of Africa Region, Holiday Inn Nairobi, September 22-24, 2008.

Gelson Tembo, Priscilla Hamukwala, Donald W. Larson, J. Mark Erbaugh, and Thomson H. Kalinda 2008. "Adoption of Improved Technologies by Smallholder Cereal Producers in Siavonga District of Zambia." Revised paper prepared for USAID/INTSORMIL, University of Nebraska and The Ohio State University project. Columbus, Ohio.

Fredy T. M. Kilima, Emanuel R. Mbiha, J. Mark Erbaugh and Donald W. Larson. 2008. "Adoption of Improved Agricultural Technologies by Smallholder Maize and Sorghum Farmers in Central Tanzania." Revised paper prepared for USAID/INTSORMIL, University of Nebraska and The Ohio State University project. Columbus, Ohio.

Product and Market Development for Sorghum and Pearl Millet in West Africa

Project PRF 102
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Lloyd Rooney, Professor, Texas A&M University, College Station, TX

Introduction and Justification

The overall objective of this project is to facilitate the development of markets for high quality processed sorghum and millet products mainly in urban areas of the West Africa Sahelian region (Senegal, Mali, Burkina Faso, Niger and northern Nigeria) through extension of processing technologies to NARS food technology laboratories and entrepreneurs for product commercialization. Related to this, activities also focus on improvement of grain and flour properties (nutritionally-enhanced sorghum and method to make seed proteins functional in leavened bread systems) for improved utilization and competitiveness. This addresses a need in Africa to find other avenues for farmers to sell their grain and to receive premiums associated with industrial uses.

In the past year, we have been involved in three activities: 1) incorporation of the high digestibility/high-lysine mutant sorghum in composition bread, 2) continued work on the pregelatinized 'instant' flour project, and 3) launching of the processing part of the larger USAID Mali mission-funded project "Transfer of Sorghum, Millet Production, Processing and Marketing Technologies in Mali" aimed to increase farmer's incomes through expanded markets. During this period, three Senegalese scientists visited Purdue food science laboratories for training and planning purposes. Additionally, the PI traveled three times to West Africa to meet with M. Diouf (consultant) and Y. Kouressi (IER scientist), to identify entrepreneur partners and later launch the Mali processing project (February and August), deliver presentations on newer technologies for sorghum and millet processing at ITA in Dakar (February), the Galweye Hotel in Niamey (February), to participate in a workshop in Bamako organized by J. Sanders and O. Botorou (August) on opportunities to expand sorghum/millet processing in the region, and help conduct an INTSORMIL regional all-PI meeting in Bamako (April).

Previous work partly supported by this project showed that maize zein storage proteins can be made viscoelastic similar to wheat gluten proteins to produce a leavened bread product. We have extended this work to test the hypothesis that the analogous sorghum protein, kafirin, can be made likewise functional to an extent that higher amounts of sorghum flour can be incorporated into composite flour leavened baked products. Such proteins in both sorghum and maize normally exist in the form of rigid protein bodies (~1 μm in diameter) that do not break apart in normal mixing to release the protein for viscoelastic fiber formation. Instead, we have used the high protein digestibility/high-lysine sorghum mutant (non-transgenic) developed at Purdue as it has protein bodies of irregular shape with potential for a melding and interaction of the kafirin protein. Studies this year show, at an incorporation level of 50% mutant sorghum/40% wheat flours, an improvement in dough properties and loaf volume over normal sorghum at the same mixture level. These are not optimum breads at this point, however these studies do show conceptual proof that sorghum kafirins can be made to functionally participate in bread making.

Work shows the potential of a pregelatinized 'instant' sorghum flour product in West Africa. This output from the Master's thesis project of M. Moussa at Purdue showed that instant flours produced using a high shear, low pressure continuous mixer make thin and thick porridges were preferred compared to those traditionally made using the same starting grain. The INTSORMIL Niger food technology project is actively seeking funding to set up a pilot-scale processing facility at INRAN with the design to work with local entrepreneurs and to test the product in the marketplace.

In Mali, a project was launched in the Mopti/Gao region in the north that included selection of six entrepreneur partners who will be working with our team (M. Diouf, consultant, Y. Kouressi, IER cereal scientist, B. Hamaker) to introduce new processing technologies to process more competitive sorghum and millet products for market expansion of these grains. This effort ties into the larger on-going work of J. Sanders and O. Botorou aimed to increase farmer's incomes through market expansion.

Objectives and Implementation Sites

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. Implementation sites are ITA, Dakar, Senegal; IER, Bamako and Mopti, Mali; IRSAT, Ouagadougou, Burkina Faso; INRAN, Niamey, Niger; and University of Maiduguri, Maidurguri, Nigeria.

Specific Objectives

- Through the buy-in project from the Mali USAID mission, work to create successful incubation center at IER to assist entrepreneurs in establishing six millet and/or sorghum processing enterprises in the Mopti and Gao regions of northern Mali,
- Facilitate the optimization of products and processes through a partnership approach between West African NARS food technologists and entrepreneurs,
- In collaboration with Institut de Technologie Alimentaire in Dakar and with G. Ejeta, continue work towards the goal of enhancing wheat-like properties of sorghum grains for high incorporation of sorghum (high digestibility/high lysine mutant lines) into baked products (mainly bread),
- Further develop, refine, and transfer technologies to appropriate West African NARS food technology laboratories to make high quality sorghum and millet processed foods (e.g., pregelatinized "instant" sorghum, agglomerated products, and millet flours for thin and thick porridges),
- Continue previous collaborative work on nutritionally-enhanced sorghum lines developed at Purdue to further improve grain quality and to test in sites in East and West Africa,
- Train two West African young scientists, one to the Ph.D. level (Malian, Mohamed Diarra at University of Maiduguri under advisement of Prof. Iro Nkama and B. Hamaker) and the other to the M.S. level (Senegalese, Aminata Diatta at Purdue).

Research Methodology and Strategy

Senegal: Continue current collaborative work with A. N'Doye, interim Director General for ITA, on product optimization and testing work on the wheat-like properties of sorghum proteins and high incorporation of the high digestibility/high lysine sorghum mutant into composite flour baked products. We will extend our current baking optimization trials and work towards field trials in the private sector. Project beginning date – October 2007, ending date – September 2011.

Niger: (1) Our overall aim has been to achieve commercial processing of high quality sorghum- and millet-based products (agglomerated - two sizes of couscous products and degue) and flours. Moustapha Moussa obtained his M.S. from Purdue in May 2007 and has returned to Niger to become a scientist at INRAN. Our work now focuses on further development of pregelatinized flours and agglomerated products for urban markets and assisting in gaining funds for an entrepreneurial unit. This processed product marketing objective is linked to the hybrid development program of I. Kapran. Project beginning date – October 2007, ending date – September 2010.

Mali: Through Mali USAID mission support of the project "Transfer of Sorghum, Millet Production, Processing and Marketing Technologies in Mali", a entrepreneurial-based processing project was scheduled to be launched in 2008 in Mopti (consultant Mamadou Diouf of ITA/Dakar, Y. Koureissi of IER/Mali, and B. Hamaker). Future activities will involve assisting entrepreneur(s) with technology expertise (training workshops), basic equipment procurement, and linkage with the grain contracting project of J. Sanders and O. Botouru. Project beginning date – October 2007, ending date – September 2010.

Nigeria: Develop a project on millet processing with funding additionally through PRF-102 for graduate student training at University of Maiduguri. Project beginning date – October 2007, ending date – September 2011.

Burkina Faso: Collaboration with B. Bougouma on millet processing and millet varietal differences suitable for specific processes; expand focus from screening of varieties to commercial products. Work through the regional West Africa program. Project beginning date – October 2007, ending date – September 2011.

U.S.: 1) Continue research project on making sorghum (and perhaps millet) grain storage proteins behave as wheat gluten to make leavened products. This follows recent work of ours showing the same for maize storage proteins (zeins). Project beginning date October 2007 –, ending date – May 2010. 2) Obtain a new graduate student from the West Africa region to work on the bread making project. Project beginning date – January 2009, ending date – December 2010. 3) Continue to work with G. Ejeta toward further improving grain quality of high protein digestibility (and possibly wheat-like property) sorghum. Project beginning date – October 2007, ending date – September 2011.

Research Results

Sorghum/Wheat Composite Bread

The hypothesis pursued in this project rests in previous work in our laboratory, partly funded through INTSORMIL, showing that maize zein proteins can be made functional to behave similar to wheat gluten, thereby forming a viscoelastic dough that can make a leavened bread product. Sorghum grain, as well as millet, has analogous proteins called kafirins (for sorghum). In studies this year, both at Purdue and ITA/Dakar, we investigated whether it is possible to mobilize the sorghum kafirins so that they participate in viscoelastic properties of dough. Our objective of this ongoing research is to examine the potential of using our high

digestibility/high-lysine mutant sorghum (non-transgenic), which has kafirin proteins existing outside the confines of typical protein bodies, at high incorporation rates with wheat flour to make acceptable bread products. Our goal is to substantially increase the amount of sorghum flour that can be incorporated into composite breads and associated products both to increase market opportunities for local sorghum farmers and to reduce need for imported and often high priced wheat.

In this first year of the project, proof of concept was shown that kafirin proteins can be made functional in a dough and bread making system. At 50% incorporation level of the sorghum mutant flour with wheat flour, the dough was noticeably more viscoelastic than the control with 50% normal sorghum flour (Figure 1a). Likewise, the bread had somewhat higher loaf volume and the crumb texture was more viscoelastic (Figure 1b). While these are not optimum breads, the finding that kafirin proteins, when released from the confines of protein bodies, can participate in dough formation and bread leavening, gives promise to the idea of a sorghum type that could have high incorporation in composite flour baked products.

Pregelatinized 'Instant" Flour for Thin and Thick Porridges

Pregelatinized 'instant' sorghum flour was the M.S. thesis research topic at Purdue of M. Moussa who returned to INRAN, Niamey, Niger in 2007. The novel aspect of this project was the "continuous mixer" used to produce the product. This is a low moisture, high shear, and low pressure system that processes a gelatinized flour that does not require further drying, and is then ground to an flour. This was used in sensory tests in four locations in Niger as was previously reported. In all cases, the 'instant' flour made thin and thick porridges that sensory panelists rated significantly higher than traditionally made porridges made from flour of the same grain.

The process was further optimized to produce fully gelatinized flours with high viscosity. Our objective is to find funding for installation of an entrepreneurial level unit in Niamey for demonstration, training, market testing, and further process optimization purposes. In this year, a proposal was submitted to a funding group in Niamey and presentations were made to a number of NGO's regarding the process and market potential of these products. All processing projects at INRAN are done in integration with the breeding group and Marketing-Processing project to meet the overall objective of promoting new high quality hybrids and expanding markets for farmers.

Mali Marketing-Processing Project

As noted above, USAID Mali mission has provided funds for the project "Transfer of Sorghum, Millet Production, Processing and Marketing Technologies in Mali". The goal of the project is to increase farmer's incomes through activities concentrated on expanding markets for sorghum and millet. In our processing part, our team is comprised of M. Diouf, consultant to the project and former ITA staff and director of the PROCELOS/CILS project in

Figures 1a: (left) shows baking scientist Ibrahim M'Bhaye of ITA, Dakar making bread dough with 50% high digestibility/high-lysine mutant (non-transgenic) sorghum flour with improved viscoelastic properties compared to 50% normal sorghum flour.

Figure 1b: (right) shows 50% sorghum mutant bread on the left and 50% normal sorghum bread on the right; both loaf volume and crumb structure were improved with the mutant flour.

West Africa for 9 years, Y. Kouressi, IER cereal scientist and doctoral candidate at Wageningen University, the Netherlands, and B. Hamaker. Djibril Drame, on leave from IER and heading a food processing project in the Mopti region, and Mamarou Diourte, an INTSORMIL regional coordinator from IER, also are assisting. In the first year, the team made two trips to the project site in the Mopti/Gao region in the north. In February 2008, meetings were made with potential partner entrepreneurs in the region as well as FENATRA, the Mali food processor association headquartered in Bamako. Six processor groups were identified, four in the Mopti area and two in Gao.

In August, the team traveled to Mopti to formally launch the project and to start initial training on processing high quality, competitive products for the marketplace. The first training workshop will be in early 2009 on basic mechanization of processing units, high product quality, and management of enterprises.

Training

Three non-degree scientists trained at Purdue University during the year, all from ITA, Dakar, Senegal. Djibril Traore, a doctoral student in nutrition sciences at Oklahoma State University, spent 2 weeks in June 2008 working on fonio beta-glucan carbohydrate structure and function. Djibril worked with us before on glycemic index studies of sorghum, millet, and fonio. Aminata Diatta trained for 6 weeks beginning in September 2008 on sorghum/wheat composite breads, and to improve her English skills. It is expected that Aminata will begin her M.S. studies at Purdue in 2009. Ababacar N'Doye, acting Director General of ITA, visited Purdue for 2 weeks in September 2008 for purposes of strategic planning, proposal writing, and work on the sorghum/wheat composite bread project.

PRF-102 additionally is funding Mohamed Diarra from IER, Mali to attend the University of Maiduguri, Nigeria for his Ph.D. studies. Mohamed's start date was delayed to January 2009. He will be under advisement of Dr. Iro Nkama, INTSORMIL regional PI and B. Hamaker.

Networking Activities

In April 2008, co-U.S. coordinator and B. Hamaker organized a West Africa Regional Program all-PI meeting held in Bamako. In addition to regional PI's, six INTSORMIL US-PI's, J. Yohe and J. Frederick from the ME, B. Duguma from USAID/Washington, O. Botorou from Marketing-Processing project, and representatives from USAID Mali, ICRISAT, CORAF, and Sasakawa Global 2000 attended. Activities included development of our regional strategic plan, networking, and finalizing workplans.

In August, B. Hamaker attended and presented at the Marketing-Processing project workshop held in Bamako. Afterwards, M. Diouf, Y. Kouressi, and B. Hamaker formally launched the processing sub-project in Mopti with partner entrepreneurs. A cereal processing training workshop is planned for early 2009.

Publications and Presentations

Journal Articles

Tesso, T., Hamaker, B.R., and Ejeta, G. 2008. Sorghum protein digestibility is affected by dosage of mutant alleles in endosperm cells. Plant Breeding 127:579-586.

Kean, E.G., Hamaker, B.R., Ferruzzi, M.G. 2008. Carotenoid bioaccessibility from whole grain and degermed maize meal products. Journal of Agricultural and Food Chemistry 56:9918-9926.

Presentations

Hamaker, B.R., Mejia, C.D., Goodall, M.A., Petros, D.D. The potential of non-wheat cereal prolamins to function in bread making, American Association of Cereal Chemists annual meeting, September 2008, Cereal Foods World 53:A29.

Development of the Input and Product Markets in West Africa for Sorghum and Millet

Project PRF 103

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Introduction and Justification

For any agricultural research program to be successful there needs to be results on farms. The farm level effect has been a weak point of both national and international agricultural research programs in sorghum and millet in Sub Saharan Africa. Contributing to this failure have been the popular promotion of low input agriculture and the perception that sorghum and millet are subsistence crops. Increasingly it is being realized that low inputs mean low outputs especially in the African context of low fertility soils and failure to use adequate inorganic fertilizers. In Sub-Saharan African whether the cereal is consumed or sold it still needs the basic crop nutrients of N, P, and K. New cultivars are also needed to take advantage of the increased soil fertility levels[1]. Water harvesting technologies reduce the riskiness of these higher fertilizer levels. Other agronomic improvements can also be required regionally. These innovations, when combined with the improved prices from the marketing strategies, not only increase yields but more significantly increase farmers' incomes.

To pay for inorganic fertilizers especially with their rapidly rising prices with the increases of world oil prices, farmers can unify to get bargaining power from farmers' associations and to introduce a series of marketing strategies. The farmers' associations enable the farmers to sell and buy in quantity with potential benefits on both the prices paid and the costs for inputs. The marketing strategies include producing a higher quality product and obtaining a price premium for the quality improvement. Moreover, the marketing strategies enable farmer responses to the annual and the between year, good weather price collapses. As the farmers' associations mature we will move to inventory credit programs either financed by bank loans or by the farmers' association. This is our primary strategy to obtain benefits for farmers from the seasonal price fluctuations. Farmers have pressing financial requirements at harvest time so prices traditionally collapse then. Inventory credit provides cash at harvest while still allowing the farmer to sell his grain later in the season[2]. The good season price collapse requires the development of new markets to reduce its effects. Our program collaborates with food and livestock nutrition scientists to help develop the food and feed markets for these crops. Another more difficult policy objective is convincing public policy makers not to depress the higher cereal prices of the bad rainfall years.

The combination of the introduction of both new agricultural technologies and a series of new marketing strategies to increase farm prices is a central innovation of this project. In the summer of 2008 there will be approximately 1,143 ha and approximately that many farmers involved in this combined technology-marketing strategy introduction in the three Sahelian countries of Niger, Mali, and Senegal.

Objectives and Implementation Sites

The principal focus of our program continues to be getting new sorghum and millet technologies onto farmers' fields in the three Sahelian countries of Niger, Senegal and Mali. The new technologies include improved cultivars defined in collaboration with the national agricultural research institutes, inorganic fertilizers, seed treatments, water harvesting techniques, and the introduction of tarps to keep the grain off the ground during threshing. These technologies are combined with a series of marketing strategies to get higher prices for farmers enabling them with the higher yields and prices to pay for the increased input levels. Finally, the third objective of our program is to facilitate the growth of strong farm-

1. Besides being higher yielding with shorter, squatter cultivars, new cultivars often have specific resistances to diseases and insects. But the ability to respond to the higher fertility levels is critical for this technology combination. Traditional cultivars tend to be selected over time for low yield variability under adverse conditions and do not respond well to higher soil fertility and water availability conditions. Their response to these higher input levels is stalk growth and lodging rather than increased grain production.

2. There are two ways to implement this program. First the farmer can retain ownership and repay the farmers' association for storage, interest, and principal for providing credit at harvest. Or the farmers' association can buy the crop at harvest, sell it for the farmers and then divide profits proportionately to the grain sold after deducting storage and interest costs.

Table 1. Area in New Technology in the Production-Marketing Project of INTSORMIL in 2008

		2008	Specific Site
Senegal			
	Millet	250[1]	Thiare
	Sorghum	35	Nganda
Total		285	
Niger			
	Sorghum	140	Gabi
	Sorghum	100	Maraka
	Sorghum	30	Safo
	Sorghum	30	Angoua Mata
	Sorghum	20	Dan Arao
	Millet	60	Doutchi
Total		380	
Mali[2]			
	Sorghum	100	Kafara
	Sorghum	78	Diola
	Sorghum	100	Koutiala
	Sorghum	50	Kolokani
	Millet	150	Tingoni
Total Area		478	
Overall Total Area		1143	

Source: Put together by Botorou Ouendeba from the reports of the national research and extension agencies collaborating with the Production-Marketing Project of INTSORMIL.

ers' organizations. These organizations, which already handle input credit and grain storage, will engage in inventory credit in the future.

In 2008 field activities were increased by 150 ha in Mali with the financial support of the Mali USAID program. We moderately increased activities in Niger and Senegal with support from this INTSORMIL program (PRF 103). This included an additional 40 ha in Niger and 60 ha in Senegal (25 ha financed by the farmers' association of Thiare). Our overall total is 1143 ha in new technologies in the three countries (Table 1). We plan to double the Mali area from 500 to 1,000 ha in the summer of 2009.

Research Methodology and Strategy

There are two principal objectives of the research activities of 2008 to support the extension program. First, we research the marketing activities. We documented the increased value of clean cereals and indicated to food processors the price premium they could afford to pay based upon the higher value of the clean uniform grain. Secondly, we make annual estimates of the income gains to farmers from our program. This starts with the yields and then income estimates are made separating the effects of the technology introduction and the new marketing strategies.There is a lag with this analysis since we need to wait until the grain is sold and the farmers associations wait for the price recovery until April[3]. So the reporting here is for the production season of 2006.

The introduction of plastic or tarp ground cover is a fundamental aspect of the Production-Marketing Project to avoid impurities in the grain (Picture 1). The estimated average impurities in millet purchases according to the processors interviewed was 13% (see Bulletin 7 of INTSORMIL). At a millet price of 100 CFA/kg and a cost of cleaning the grain of 10 CFA/kg that gives a price premium of 23 CFA/kg. One of the principal objectives of the summer workshop in Bamko (see networking) was to present these survey results and calculations for the price premium to the millet food processors as we continue to lobby for higher prices for farmers. These higher prices help raise incomes and enable farmers to continue investing in higher input levels.

The Production-Marketing Project has been most successful in the lowest income, most difficult agricultural region of the three countries, i.e., eastern Niger. The introduction of improved sorghum technologies requires the simultaneous introduction of a series of labor intensive agronomic practices including replanting, thinning, weeding and the construction of water harvest techniques. In the high population pressure, low income region of Maradi farmers are doing regularly these practices and substantially increasing yields. They have fewer alternatives in or out of agriculture than farmers in the other countries so they invest more labor in raising their returns from this technology introduction. Compared with traditional farm yields of 500 to 600 kg/ha of sorghum in the region average yields of the new technologies are almost tripling the traditional sorghum yields in Gabi and Maraka (Table 2). The new cultivar is a short stature Caudatum cultivar called Sepon 82. This cultivar has been in the region since the early '90s but never before systematically combined with moderate fertilization and improved agronomy (Picture 2). Project farmers have been selling the Sepon 82 seed to both Niger and Nigerian farmers. The introduction of the Sepon 82 alone has become very popular in the greater region.

3. If they could wait longer, the product price tends to go even higher. However, they need the cash from this rotating fund to buy inputs for the members for the coming crop season.So they have to sell before the end of April to buy the inputs in May.

Picture 1. Farmers threshing sorghum on a tarp in Tingoni, Mali.

Source: T. Abdoulaye et al., 2008, p. 11. Photo Credit. Sandinan Camera, SG, 2000.

The critical thing in the introduction of any new technology is whether it is profitable to farmers. The income effect from comparing these cultivars to traditional ones are summarized in Table 3. The technology effect compares traditional and improved yields. The price effect uses the prices received by the farmers' association from selling later in the season, in larger quantities, and a cleaner grain compared with the harvest price received by farmers in the region. The results for sorghum in 2006 show staggering gains from both the technology introduction and the marketing strategy.

As farmers acquire more experience with the agronomy and marketing aspects, they are expected to plant on their best land and to follow the agronomic practices. This will enable them to approximate the best farmer yields of 2.3 to 2.5 tons/ha. Our main program emphasis now is to obtain these same types of cultivars and yields in Mali and Senegal (see sections VIII and IX of this report for further information on the success of new cultivar introduction in Mali in 2008 and expected in Senegal in 2009).

Training

Felix Baquedano is presently writing his Ph.D. thesis on the income alternatives in one cotton region, Dioila, of Mali. New sorghum activities are being tested there. So he is looking in detail at our sorghum technology extension program and comparing it with various new activities in cotton. He is also evaluating different marketing strategies.

On the 1,143 ha of new technology activity of the Production-Marketing Project in 2008 there were approximately that many farmers[4]. This introduction of new practices is combined with improved agronomy and marketing strategy. Farmers need to be trained in these practices. We can only train a small number of these farmers but field days are encouraged and the farmers talk to each other.

Finally our workshop described below involved three days of presentations, discussions and two field visits for 38 participants.

Network Activities

On August 12-14 we held in Bamako, Mali a workshop entitled "Building Value Chains for Millet and Sorghum Processing." The workshop was designed to improve ties between food processors of millet/sorghum with farmers' association representatives and between food scientists and both of these groups. The workshop included visiting farmers' fields of the farmers' association of Tingoni and one of the millet food processors in Bamako (Mme Demb). The concentration was on Mali (23) but there was also representation from Niger (3), Senegal (5), Benin (1), and INTSORMIL (U.S.-6).

Specific objectives were to demonstrate to food processors the calculation of a price premium based on increases in value as well as to reinforce to the farmers' associations the continuing importance of improving the quality of their cereals for the processed food markets. Another objective was to convince millet food processors of the potential for the partial substitution of sorghum for millet as in done in other countries. South Africa and Japan make excellent processed food products from sorghum.

Publications and Presentations

Mme Toure Aminata, T. Abdoulaye, J. Sanders, and B. Ouendeba. Transformation Commercial du Mil et du Sorgho au Mali, Proj-

4. We attempt to limit participation to one farmer per ha. In practice those influential in the village and farmers' association often end up with more than one ha. Then we put pressure on the farmers' association to reduce farmer holding to one ha per farmer. In the heavy population pressure Nigerien sorghum holdings farmers often have less than one ha with as many as four farmers per ha.

ect Production-Marketing, INTSORMIL Bulletin No 7, INTSORMIL, University of Nebraska, Lincoln, Ne., November 2007, 38 pages.

Tahirou Abdoulaye, John Sanders, and Botorou Ouendeba, Evaluation of Sorghum and Millet Technology and Marketing Strategy Introduction: 2006-07 Crop Year, Project Production-Marketing, INTSORMIL Bulletin No 8, INTSORMIL, University of Nebraska, Lincoln, Ne., November 2007, 23 pages

Table 2. Sorghum yields (kg/ha^{-1}) in Niger from farmers' estimates and crop cuts, 2006

Village	Crop	All Farmers		
		Interviews	Crop cuts	Best Farmers' Interview
Gabi, Maradi	Sorghum	1440	2140	2542
Maraka, Maradi	Sorghum	1397	1670	2337

Source: T. Abdoulaye et al., 2008, p. 8 Note: Best farmers average yield of 6 farmers with sorghum yields higher that 2 tons per ha

Picture 2. Farmers' visit on a field day in Maraka, Niger with an improved cultivar and inorganic fertilizer.

Source: T. Abdoulaye et al., cover. Photo Credit: Botorou Ouendeba.

Table 3. Estimated income gains from sorghum technology and price effects based on average and best farmers' yields, Niger 2006.

	Gabi (Sorghum)		Maraka (Sorghum)	
	Average	**Best Farmers**	**Average**	**Best Farmers**
Technology effect, %	92	292	28	193
Price effect, %	87	153	108	212
Total gain, %	179	445	136	405

Source: T. Abdoulaye et al., 2008, p. 15.

Product and Market Development for Sorghum and Pearl Millet in Southern Africa and Central America

Project TAM 103

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Introduction and Justification

This project's major activities relate to objectives 1 and 2 on supply chain management and development of super healthy foods from sorghum. It provides for education of students on new, more effective ways of processing sorghum / millet into profitable food products. Extensive breeding and analysis of sorghums for flavanoids is ongoing.

Major activities include work in Central America to utilize sorghum as a substitute for costly wheat flour in a wide array of foods. CENTA in El Salvador has been quite effective.

The project has worked effectively with Professor Taylor in South Africa (University of Pretoria) to educate students from Botswana, Zambia, Namibia and South Africa on sorghum and millet processing. This effectively maximizes use of our limited funds to assist in education of African students because of the reduced costs. We are developing a "sandwich" Ph.D. degree for M.Sc. Chiremba of the Agriculture Research Council (ARC) in South Africa.

We participated in workshops in Central America and West Africa to educate and provide information to scientists, PVO's and NGO's interested in supply chain development. We worked with other INTSORMIL CRSP projects in economics, grain marketing and food science to promote healthy foods from sorghum using supply chain management.

Objectives and Implementation Sites

We have focused our efforts on improving the utilization of sorghum in Central America and Southern Africa. More specifically, key targets are El Salvador and South Africa. We are working with Ms. Calderon, who completed her M.S. thesis at Texas A&M and returned in September 2007 to El Salvador; she is leading efforts to utilize sorghum in food systems. We are using her expertise to assist Ms. Palacio in Nicaragua (INTA).

We are working with Professor Taylor, University of Pretoria and his associates to provide education and key research activities that apply to utilization of sorghum and millet in Southern Africa. University of Pretoria has a strong program in food science and technology with significant numbers of students from African countries.

In addition, the PI has provided support for value added supply chain activities in West Africa led by Dr. Sanders at Purdue. These projects are making a significant impact on production and use of millets and sorghum by small processors and entrepreneurs. The objectives are:

1. Facilitate the growth of rapidly expanding markets for sorghum and millet products by providing information (skills or know-how) on nutritional properties, processing quality, food manufacturing processes with improved efficiency, and prototype products using sorghum/millet as an ingredient.
2. Improve the food and nutritional quality of sorghum and pearl millet to enhance their marketability and image as

grains that promote healthy wholesome convenience foods.
3. Contribute to host-country institutional human capital development through short-term and long-term educational opportunities. Non-degree (short-term) training will include research methodology and conferences or hands-on training workshops; degree (long-term) training includes M.S. and Ph.D. programs.
4. Provide practical technical assistance and information on supply chain management and processing technologies, plant management and related matters.

Central America, especially El Salvador, made significant progress in using sorghum flour to replace expensive wheat flour and corn in baked products and ethnic foods. The other major research site was Southern Africa where collaboration with Professor Taylor, University of Pretoria, and other research groups has been excellent.

Research Methodology, Strategy and Role of Host Country Scientists

The host country scientists in the project are well-educated, experienced and are truly working as colleagues to provide leadership for the activities. Information and technology generated flow both directions and is synergistic in nature. The teams have a significant number of experienced scientists who provide leadership and advice to younger scientists involved. For example, Dr. Kebakile completed his Ph.D. at University of Pretoria and returned to Botswana to conduct processing research on sorghum and millet. He is a good scientist and provides excellent leadership in the Botswana Food Processing Center.

The Agricultural Research Council (ARC) in South Africa has significant efforts in grain quality evaluations of new cultivars. Interaction with that program accentuates efforts to improve quality and productivity of sorghums. We are planning a training program for M.s. Chiremba at Texas A&M as part of her Ph.D. program at University of Pretoria with Professor Taylor and L. Rooney, TAMU.

Results/Significance

Sorghum for Healthy Foods: Specialty sorghum varieties have potential health benefits with high antioxidant levels and reduced starch digestion. Different levels of phenolic compounds significantly ($p<0.005$) affect the rate of starch digestion and estimated glycemic index (EGI) of sorghum products. White, high-tannin, black, and black with tannin sorghum varieties were used to investigate starch digestibility and EGI of whole sorghum porridges.

Porridges made with sorghum varieties containing high levels of condensed tannins and anthocyanins had significantly ($p<0.001$) lower starch digestion rates ($k=0.06$-0.09) and EGI values (78-86) than porridges made with whole white sorghum ($k=0.11$, EGI= 91) and whole white corn ($k=0.12$, EGI= 95).

Research has confirmed that special sorghums containing condensed tannins and high levels of flavanones, flavones and 3-deoxyanthocyanins exist. They are quite high in anti- inflammatory compounds that are difficult to find in natural sources. In addition, whole grain high tannin sorghums and their brans significantly reduce the estimated glycemic index (EGI) of foods. Cooking tannin bran extracts with corn starches significantly reduced the EGI in model system porridges. Cooking starches with tannin sorghum extracts significantly decreased EGI and enhanced resistant starch because the tannins reacted with protein and other components in porridges.

The black sorghums contain high levels of unique 3-deoxyanthocyanins that have stability to pH, temperatures, and water activities. Their stability is equal to commercial Red Dye #40 and Red Dye #3. Natural colorants from sorghum with more stability than fruit and vegetable colorants are promising.

Our research on these special sorghums has stimulated several research groups to initiate research on sorghum as a health food. The use of sorghum in developing healthy foods and as a source of beneficial compounds improves the image of sorghum and should lead to significantly greater use in nutraceutical foods worldwide. The desirable components are concentrated mainly in the pericarp which can be easily removed to concentrate the materials. The new sorghum hybrids containing these compounds have reasonable yields.

Sorghum Has Promise to Lower Cholesterol in Animals: The phenolic composition of brans obtained from Sumac (high tannin) and Shawaya (black) sorghums were used to determine their hypocholesterolemic effects when brans were fed to hamsters. Both sorghum brans and 80% methanol extracts of bran decreased plasma and liver cholesterol and improved the LDL/HDL ratio in hamsters. Thus, the data suggests that high tannin and black sorghum brans may be used as natural therapy to lower total and LDL-cholesterol and prevent cardiovascular diseases.

Potential anti-cancer compounds extracted from tannin sorghum were obtained using fast centrifugal partition chromatography (FCPC). This separation technology allowed recovery of enough natural products for testing in colon (Caco-2), hepatic (HepgG2) and hormone-dependent mammary (MCF-7) cancer cells. Some tannin sorghum compounds besides flavonoids have potential for inhibiting colon and hepatic cancer. A compound with molecular formula $C17H30O3$ or $C18H34O2$ is a candidate for anticancer activity observed in the fractions obtained by FCPC from the methanolic extract of tannin sorghum.

Phenolic Profile, Antioxidant Activity and Anticancer Properties of Different Types of Sorghums and Brans: The phytochemical profile of 25 different types of sorghums/brans was evaluated for potential as anticancer agents using in vitro colon (Caco2), hepatic (HepG2) and hormone-dependent mammary cancer (MCF-7) cell lines. Genotypes included white, red, yellow and black, (type II), and high-tannin or brown (type III) sorghums. The hydrophilic and lipophilic antioxidant activities (ORAC) were evaluated and correlated to total phenolics, flavonoids, anthocyanins and tannins and to the inhibition of the three different cancer cell lines.

- Among the different sorghum samples analyzed, several showed high antioxidant activity and significant inhibition of

MCF-7 cells.

- A significant negative correlation between tannin content and hormone-dependent mammary cancer cell inhibition was observed. Sorghum genotypes containing condensed tannins had the best potential as natural anticancer agents.
- Almost all samples had antiproliferative activity at least in one of the cancer cell lines evaluated. Hormone dependent mammary cancer cell viability was the most affected by sorghum methanol extracts.

Highly Digestible Sorghums: Progress was made in developing improved mold resistance in sorghums that have genes for improved protein digestibility. The original highly digestible types developed by Purdue University are quite susceptible to molds. The new lines developed at TAMU appear to have increased resistance to molding and were tested for use in malting and brewing and ethanol production. Dr. Hays has demonstrated that they produce significantly higher levels of alcohol (up to 15%). Preliminary information from Prof. John Taylor at University of Pretoria indicates that they produce slightly higher levels of free amino nitrogen (FAN) during malting. Increased levels of FAN would be highly useful for malting. These types with extra lysine may be adapted for production in areas of the world where the grain matures during very hot, dry conditions. Ideally they could be used in Sudan, Ethiopia and similar places. In humid areas during grain maturation, there must be improvement in resistance to molds.

Outreach Activities: Several fact sheets and posters contributed from this project are on the INTSORMIL website. They summarize information for use in understanding factors affecting composition and sorghum quality; they provide information on tannins.

- Myths about Tannins (in English, French and Spanish)
- Sorghum Composition, Structure and Quality
- Antioxidant Activity in Sorghum Bran Diets and Their Effect on Colon Cancer
- Decortication Level and Particle Size Effect on Direct-Expanded White Sorghum Extrudates
- Antioxidant Properties of Sorghum Assessed by Three Methods
- Bongos® the Cool Snack™
- Corn Tortillas Enriched with Brown Sorghum Bran
- Effects of Bran Fortification on Physical Characteristics and Antioxidant Activity in High Tannin Sorghum Extrudates
- Effect on Whole Sorghum Extrusion Performance and Products
- False Positives for Tannin Sorghum in Non-Tannin Sorghum Using the Bleach Test
- Grain Quality Analysis of Sorghum Cultivars from El Salvador, C.A.
- Developing Quick Methods to Cook Whole Sorghum
- Market Development for White Sorghum
- Vita Bread®
- Properties of White Food Sorghums Grown in Different Environments

Training (Degree and Non-Degree)

Three Ph.D. and three M.S. degrees were awarded to students working on sorghum. This includes Ms. V. Calderon who returned to CENTA, in El Salvador, to provide leadership in sorghum use in food systems.

L. Rooney collaborated with Professor Taylor, University of Pretoria, South Africa, on one M.S. thesis and a Ph.D. dissertation that were completed. Another Ph.D. and M.S. are in the pipeline at the University of Pretoria.

"Sandwich" degree programs reduce the costs of obtaining degrees to enable education of more students while providing them exposure to U.S. universities and related technologies. Ms. Constance Chiremba, M.S. student, University of Pretoria, was selected for short-term training at Texas A&M University. She is a technician in charge of sorghum quality evaluations at ARC in South Africa.

International Foundation for Science (IFS) Workshop: IFS sponsored a workshop for young African food scientists in Pretoria, South Africa in November 2007. L. Rooney presented information at the conference which was organized by Professor Taylor and the University of Pretoria. These young, newly-educated scientists were mentored and helped to develop potential research projects for submission to funding agencies.

Topics presented included the role of supply chain management in developing sustainable technology from African grains including millets and sorghum. Topics ranged from natural sorghum plant dyes to new foods from millets and sorghum.

Supply Chain Activities: L. Rooney participated in workshops held in Bamako, Mali (August 2008) and Dakar, Senegal (December 2007) on supply chain developments for food and feed by discussing the effective ways to make the chain work.

Short Courses: L. Rooney assisted Ms. V. Calderon CENTA, El Salvador in developing milling technology/short courses materials for interaction with a large number of food processors who wanted to use sorghum in baked and other products.

More than 40 participants enrolled in a one-week short course on practical snack foods processing held at Texas A&M. Information on sorghum utilization was included in the training for these domestic and international food processors.

Short-Term: Educational opportunities (one semester) were provided to a food science student from Guatemala who was a senior at Escuela Agricola Panamericana (EAP), Zamorano, Honduras.

Many scientists in Southern Africa have been educated at the University of Pretoria by Prof. Taylor and his colleagues. Through our INTSORMIL association with this program we have assisted in producing a cadre of dedicated scientists working with food processors and others to improve quality of sorghum and millet. In turn, they educate many students from Africa in food processing and related areas.

Agricultural Research Council (ARC), South Africa: Ms. Constance Chiremba, who runs the South African sorghum quality evaluation trials, is determining the phenolics and antioxidant activity of South African sorghum cultivars and developing antioxidant-rich sorghum foods as part of her M.S. research together with Drs. Taylor and Duodu at the University of Pretoria.

Ms. Doreen Hikeezi, former INTSORMIL M.S. graduate and lecturer in the Food Science and Technology Dept, University of Zambia, initiated her doctoral research work on sorghum grain end-use quality for food and beverage applications. She is working in collaboration with Prof. Taylor, Dr. Medson Chisi (sorghum breeder) and L. Rooney.

Mr. Luke Mugode, Zambian National Institute for Scientific and Industrial Research, is nearing completion of his M.S. degree related to protein hydrolysis during brewing of sorghum. He is evaluating highly digestible sorghum cultivars developed and increased by Dr. Hays at Texas A&M University.

Mr. Stephen Barrion, University of Namibia, completed a M.S. from University of Pretoria with Taylor and Rooney on pearl millet quality. He provided key inputs into pearl millet processing quality in the network.

Dr. Martin Kebakile, Botswana, completed a Ph.D. working with Prof. Taylor and L. Rooney. He has several publications showing that the modified roller mill developed in South Africa efficiently produces improved quality sorghum flour better than the abrasive milling equipment currently used. Dr. Kebakile is an important component of the network in Southern Africa.

Central America/ Mexico: Ms. Vilma Calderon, Food Scientist, CENTA, completed her M.S. in Food Science at TAMU with Lloyd Rooney and returned to CENTA in September 2007 to lead utilization research on sorghum for food in El Salvador.

Ms. Calderon's M.S. thesis on sorghum use in foods provided useful information to meet these opportunities in promoting sorghum foods. She also provided excellent leadership to develop procedures to use the low-cost Omega VI grinders designed by Compatible Technology International (CTI) to mill sorghum into flour for use in a wide variety of products.

The Omega VI grinder was integrated with a low-cost sifter designed and constructed by K. Duville of CENTA which produced an array of flours with different properties.

After the successful use of the first Omega VI grinder, INTSORMIL purchased 4 additional Omega VI grinders. They were distributed to small processors in El Salvador who use sorghums in food systems, but needed improved grinders. We appreciate their excellent support and providing 5 Omega VI grinders at modest cost. The 4 Omega VI grinders were sent to CENTA, and 1 was presented to INTA in Nicaragua.

New varieties developed by Rene Clara, CENTA, retired sorghum breeder, with excellent food quality have been effectively used to extend wheat flour, snack foods and related products where the bland flavor and light color have real advantages.

Mr. Kris Duville, who formerly worked for a rice processor in El Salvador, assisted Ms. Calderon to conduct a large number of workshops on sorghum properties, processing and use in food products. More than 65 industrial participants were trained with special workshops for some companies. The workshops conducted in the CENTA food laboratory covered most aspects of sorghum quality and processing.

Lloyd Rooney traveled to El Salvador twice to provide assistance with processing equipment and other activities in the CENTA Food Laboratory.

The equipment purchased earlier by INTSORMIL to partially equip the CENTA food lab has been effectively utilized.

Drs. Serna-Saldivar, Professor, Monterrey Institute of Technology (ITESM), Monterrey, Mexico and Francisco (Javier) Bueso, EAP, Zamorano, Honduras have provided expertise. Drs. Serna and Rooney obtained funding from TAMU-CONACYT for testing in vitro anti-cancer activities of sorghum extracts. This led to Dr. Sara Guajardo's Ph.D. dissertation demonstrating that certain sorghums had important anticancer activities.

Interaction with Escuela Agricola Panamericana (EAP) in Honduras continues with short- training programs conducted each spring for EAP students. These students are provided training in cereal technology and related activities. L. Rooney was part of a team that reviewed the EAP curriculum.

Development of end-use markets is contingent upon availability of a dependable supply of high quality grain at prices where all parts of the supply chain can make profits. Previous INTSORMIL activity demonstrated that supply chain management linking research with farmers and end-users was crucial in generating sustainable income for all parts of the system. Sanders has made significant progress in Sub-Saharan Africa by demonstrating that food processors' sales and profits are improved by accessing a reliable supply of grain with payment of a premium.

Supply chain management allows farmers to invest in new varieties, fertilizer and other inputs because of higher earnings and more reliable markets. Thus, there are increasing opportunities for small farmers to participate in new markets and generate income. Other examples exist across Southern and East Africa where South African Breweries (SAB) is using supply chain management to secure sorghum for brewing.

Research and development proposed in this project is directed at key components of a supply chain management scheme. The plan, in conjunction with economics and marketing, can successfully expand production of cost-competitive, convenience food products of sorghum and millet for urbanized areas.

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Building a Sustainable Infrastructure for Product Development and Food Entrepreneur/Industry Technical Support: A Strategy to Promote Increased Use of Sorghum and Millet in East Africa

Project UNL 102
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Introduction and Justification

Sorghum and millet are ideal crops for many parts of Africa. Maize, however, is favored by many as a food source; farmers thus grow Maize even though on a multi-year basis sorghum is a more reliable crop. The use of sorghum and millet in food products is limited throughout the world. In many parts of Africa, there is a lack of high-quality grain plus little knowledge regarding sorghum and millet's potential use in a wide variety of both traditional and non-traditional foods. There is also little infrastructure for conveying and demonstrating the food value of sorghum and millet to those most willing to invest in its potential, namely small businesses.

Our approach involves three core initiatives in order to achieve rapid, yet sustainable, impact.

During the past year we have made progress in all three areas: a) maintenance of a business development and technical support network, b) sharing the business development educational materials and program success with others in East Africa and, and finally c) Establishing a M.S. and Ph.D. program, emphasizing Sorghum/Millet grain quality, food product development, and entrepreneurship, for East African University faculty members. Specifically, we have:

- Continued operation of the entrepreneurial assistance program in Tanzania with existing clients and established linkages with new clients.
- Shared educational materials and approaches with faculty, administrators and staff at the University of Zambia and explored sources of additional/start-up funding for their program.
- Strengthened workshop offerings for food processing entrepreneurs and educational programs for farmers.
- Begin planning of regional entrepreneurial assistance education workshop that would demonstrate program and distribute educational materials and explore additional funding opportunities in order to expand the number of workshop participants.
- Recruited and started a Ph.D. academic program of one M.S. degree-holding faculty member from the University of Zambia at the University of Nebraska's Department of Food Science & Technology.
- Recruited into a M.S. program (at the University of Nebraska) a non-research M.S. degree holder from Tanzania (his program will start in January 2009).
- Began the process of developing a systematic and objective program evaluation model.

Objectives and Implementation Sites

Our specific objectives during year 2 of this project were to:

- Continue operation of entrepreneurial assistance program in Tanzania with existing clients; start new clients through initial workshop.
- Share educational materials and approaches with staff in Zambia (University of Zambia); explore sources of additional/start-up funding for their program.
- Strengthen workshop offerings and/or educational programs to farmers.
- Begin planning of regional entrepreneurial assistance education workshop that would demonstrate program and distribute educational materials; explore additional funding opportunities in order to expand number of workshop participants.
- Recruit M.S.-level faculty members (2) into a Ph.D. program at the University of Nebraska's Department of Food Science & Technology.
- Develop a systematic and objective program evaluation model.
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These program objectives specifically address the overall CRSP objectives to “Facilitate the growth of rapidly expanding markets for sorghum and pearl millet,” “Improve the food and nutritional quality of sorghum and pearl millet to enhance marketability and consumer health,” and “Develop effective partnerships with national and international agencies engaged in the improve-

ment of sorghum and pearl millet production and the betterment of people dependent on these crops for their livelihoods." Primary implementation sites are: 1) Tanzania, 2) Zambia, and 3) training for scientists in Nebraska.

These objectives were to be implemented at the following sites:

As we have a strong partnership with Sokoine University of Agriculture, our regional efforts are coordinated from Tanzania. As funding is limited, the Food entrepreneur workshops and farmer education activities will continued to be offered in Tanzania. Our initial sharing of curricular material took place in Zambia, at the University of Zambia in Lusaka.

Our student education program emphasizing food science, product development and marketing/entrepreneurship is taking place at University of Nebraska in Lincoln, NE, USA. Marketing and entrepreneurship education will take place through internships with UNL's Food Processing Center, and the traditional educational program will be in the Department of Food Science and Technology.

Research Methodology and Strategy

This program involves three main elements to support entrepreneurial food processing businesses in Africa by developing a support infrastructure within University systems. This support infrastructure involves personnel with both scientific and businesses development backgrounds. The three main elements include: a) Engaging potential entrepreneurs/small business groups in Tanzania with an introductory workshop on food processing and marketing, b) Providing ongoing technical and business support services that are customized to individual needs, and c) Building educational infrastructure by supporting Ph.D. and M.S. training of Food Science & Technology faculty and/or governmental officials directly involved in supporting food processing businesses.

Additional activities include providing workshops for small stake-holder farmers in Tanzania (grain harvesting techniques to maintain quality) and curriculum support to other African institutions interested in Food Science & Technology / Sorghum entrepreneurship outreach programs.

Research Results

Ongoing activities are characterized in Table 1.

Details of 2008/Year 2 Program Progress

Continue operation of entrepreneurial assistance program in Tanzania with existing clients and establish contacts with new clients.

- Provide support to existing groups of sorghum processors in Dar es Salaam and Dodoma (5 groups were supported on an intensive ongoing basis.) As examples, one group was facilitated by the Project to attend the Board of External Trade (BET) trade fair in Dar Es Salaam in July 2008. Also, 3 groups were facilitated to participate in the Farmers Day exhibitions "Nane Nane" in Morogoro in August 2008. One group in Dar es Salaam, the Nzasa Women Group, was provided with the support necessary to obtain registration/certification with the Tanzania Food and Drug Authority (TFDA). Their processing premises were inspected by the TFDA and approved with minor modifications. The registration process for this group is at an advanced stage (September 2008). Once registered, their products are allowed to enter into any market (local and external markets).
- As resources are limited, it is especially important to pre-identify businesses/entrepreneurs that have a realistic opportunity to succeed when entering the program. Therefore, potential clients were identified and visited (new groups/entrepreneurs/companies) and after screening invited to be involved in the next Workshop to be held in Dar es Salaam. Baseline information about these groups has been collected and focus group discussions held. A total of 14 firms in Dar es Salaam, 2 in Dodoma and 6 in Singida have been identified as potential participants to the Workshop. Most of the identified processors are small-scale (processing up to 10 kg per day) and relatively new in the business. However three sorghum stakeholders were identified who operate on a commercial scale; (i) one miller based in Buguruni, Dar es Salaam (Mr. Faki Bakari) mills up to 20 tones of sorghum per day, (ii) one Supermarket (Imalaseko – based in Dar es Salaam) sell sells about 100-1kg packets of sorghum products per day, and (iii) one retail outlet based in Dodoma and owned by Mr. Peter Roberts sells about 30-1kg packets of sorghum products per day.

Share educational materials and approaches with staff in Zambia (University of Zambia); explore sources of additional/start-up funding for their program.

Dr. David Jackson (Principal Investigator) and Dr. Joseph Mpagalile (Collaborating Scientist in Tanzania) made a trip to the Faculty of Agriculture at the University of Zambia (UNZA). The Department of Food Science and Technology at UNZA hosted the visit. While at UNZA the team met with

- The Dean of Faculty of Agriculture
- The Faculty of Agriculture Research Coordinator
- Staff members of the Faculty of Agriculture and in the Department of Food Science and Technology
- The Acting Director of Research and Postgraduate Studies (Campus-Wide)

In addition to broad-based discussions, the team made presentations to the faculty. The talks focused on the project's background and activities being carried out in Tanzania and USA. In addition to sharing project materials, an effort was made to develop wider interest in outreach services to those interested in the food processing / sorghum processing industry.

Strengthen workshop offerings and/or educational programs to farmers.

Plans are underway to conduct farmers training to farmers in Morogoro, Dodoma and Singida regions. As of October 1st, the

Table 1.

Objective (Planned Target/Activities)	Status of implementation	Problems encountered	Corrective measures
1. Continue operation of entrepreneurial assistance program in Tanzania with existing clients and create linkages to new clients.	Five existing clients are receiving *intensive ongoing* support by Sokoine University of Agriculture (SUA) in Tanzania. SUA has further identified a total of 14 firms in Dar es Salaam, 2 in Dodoma and 6 in Singida to receive additional intensive business and technology support services.	None	None
2. Share educational materials and approaches with faculty, administrators, and staff in Zambia (University of Zambia) and explore sources of additional/start-up funding for their program.	Drs. Jackson and Mpagali made one trip to the University of Zambia in Lusaka, Zambia. They made public presentations to the Faculty of Agriculture, visited with individual staff and administrators regarding the SUA outreach program.	None	None
3. Strengthen workshop offerings and/or educational programs to farmers.	New workshops were planned; educational approaches were updated.	None	None
4. Begin planning of regional entrepreneurial assistance education workshop that would demonstrate program and distribute educational materials; explore additional funding opportunities in order to expand number of workshop participants.	Initial planning activities initiated	None (so far)	None (so far)
5. Recruit MS-level faculty members (2) into a Ph.D. program at the University of Nebraska's Department of Food Science and Technology.	Two M.S. holding students were identified, one from Tanzania and one from Zambia. The Zambian student enrolled in the fall of 2008 in a research-based Ph.D. program. No Tanzanian student was identified that had a sufficient research background to enter into UNL's Food Science and Technology program (best student had a non-research M.S. degree from the UK). This student, therefore was enrolled into our research-based M.S. program.	Delay in recruiting a suitable PhD student from Tanzania.	Recruited MSc student instead. Student will start in January 2009.
6. Develop a systematic and objective program evaluation model.	Development of the model is one of the ongoing activities.	None (so far)	None (so far)

exact dates for these programs had not been set (they will start, however, in January 2009. The training content will be similar to training offered to farmers in Melela village (Morogoro region) and Mpalanga village (Dodoma region) during the first year. The intent, however, is to reach reach more farmers by inviting more farmers per each session and having a greater number of sessions. We will, however, invite and interact with district leaders / influencers and Extension professional in order to make recommended grain-quality harvesting practices more sustainable.

Planning was initiated for the of regional entrepreneurial assistance education workshop that would demonstrate the program and distribute educational materials.

Initial planning was initiated. Specific inquires were made in regard to venue, local participation, and other in-country logistics. Beginning in January 2009, a more resources will be expended to insure this activity is completed.

Recruit and Begin Degree Programs in Food Science and Technology

One Ph.D. student was recruited from UNZA (she is a MS-holding Lecturer in the Department of Food Science & Technology) and started her program at the University of Nebraska (Fall 2008 Semester). A Tanzanian student will start his program in the Spring of 2009 (M.S. program).

Develop a Systematic and Objective Program Evaluation Model

Initial work on this output is underway which include development of a Monitoring and Evaluation (M&E) calendar. We are also developing M&E assessment grids that will objectively capture relevant economic advancement.

Networking Activities

Visit to University of Zambia (March 2008) noted earlier in the report.