N.A.R.P. LEGUMINOUS CROPS PROGRAMME

POST-HARVEST TECHNOLOGY AND UTILIZATION ASPECTS

FINAL (TERMINAL) REPORT

By

W. A. Plahar
COLLABORATOR

Food Research Institute
P. O. Box M.20
Accra.

FEBRUARY, 1999

INTRODUCTION

Applied research in grain legumes varietal quality characterization, processing and utilization is major focus of the research and development activities at the Food Research Institute (FRI). Projects in this area are formulated to develop through applied research, techniques that would facilitate the effective utilization of locally developed legume cultivars for the improvement of the nutritional and socio-economic status of the average Ghanaian. Specifically, the general objectives seek to develop and encourage the adoption of legume processing and utilization technologies appropriate for household and small-scale enterprises in order to stimulate production, encourage small enterprise development and make available more utilization technologies, thereby improving on the economic and social benefits to primary producers, processors and, rural and urban communities in Ghana.

Under the National Agricultural Research Project (NARP), projects were development and executed on soybeans, cowpea, bambara groundnut as well as on design and fabrication of appropriate machinery for processing these legumes. Projects on soybean utilization started during the first phase of the NARP in 1992, when soybean was selected as one of the three priority crops. The other legumes were added during the second phase which covered the three-year period, 1996 - 1998. Annual Technical Reports on the individual projects have been compiled and submitted each year through the Coordinator.

This terminal report summarizes the activities undertaken on the post-harvest technology and utilization aspects of the leguminous crops programme under the NARP. The report is presented with regards to the programme objectives and their evaluation, achievements of the programme objectives, major factors that have affected project implementation and post-project activities and sustainability.

1. STATEMENT OF PROGRAMME OBJECTIVES AND THEIR EVALUATION

The overall goal of the post-harvest technology and utilization research under the NARP leguminous crops programme is increased production and utilization of legumes as a major source of affordable vegetable protein for improving the nutritional status of the population. To achieve this goal, projects were designed to focus on the following post-harvest activities:

- Evaluation of improved cultivars to facilitate varietal selection in terms of both agronomic and utilization characteristics.
- Enterprise level technology development (products, processes and appropriate machinery) for specific products.
- Development and promotion of house-hold utilization technologies for improved nutrition
- Development of appropriate machinery for post-harvest handling.

Based on the above, the following five major research projects with the specific objectives were undertaken within the duration of the NARP.

A. Project # 06-065: Processing and Utilization studies on cowpea cultivars

The specific objectives were:

a. to conduct comparative studies of cowpea varieties for anti-nutritional factors and methods for their inactivation.

b. to develop appropriate techniques for pilot scale dehulling and milling of cowpea varieties

c. to evaluate cowpea cultivars in terms of their suitability for specific food uses.

d. to develop technologies for the utilization of cowpea for the production of cereal-based high protein-energy foods.

B. Project # 06-046: Evaluation of soybean cultivars for processing and utilization

The specific objectives were:

a. to evaluate soybean cultivars in terms of their anti-nutritional factors and suitability for specific food uses.

b. to develop appropriate techniques for the production and packaging of full-fat soy flour and grits as stable intermediate soy products for fortification purposes.

c. to develop appropriate techniques for the production of acceptable soybean milk.

C. Project # 06-066: Product development based on bambara groundnut

The specific objectives were:

a. To determine processing techniques that can be applied to bambara in preparation of snacks and convenience foods

b. To determine the physical, chemical, nutritional and sensory qualities of formulations

c. To assess consumer acceptability of products

d. To increase utilization of bambara in the Ghanaian diet and improve nutritional status

D. Project # 06-015: Design and construction of cleaning and grading machine for legumes.

The specific objectives were:

a. To identify the type of cleaning, sorting and grading machines used by the large-scale commercial farming and marketing agencies as well as the small- and medium-scale producers, middlemen and market retailers; and to assess their capacities and levels of operation.

b. To design and construct low-cost affordable cleaning, sorting and grading machines for grains and legumes for peasant farmers, small and medium scale producers, market retailers and marketing agencies to improve quality of products on the local market

c. To test prototype constructed machines and carry out any modifications necessary to ensure efficient and satisfactory performance of prototype machines

E. Project # 06-001: Adaptation/modification of winged bean dehulling plant to process soybean, groundnut and cowpea

The specific objectives were:

a. to adapt/modify the winged bean dehulling plant to process soybean, groundnut and cowpea

b. to develop a method of operation of the modified plant to achieve optimum output

c. to obtain data on operating parameters of the plant

d. to determine production capacity of the plant

e. to introduce the plant to food processors and the designs to local engineering companies.

About 80% of the objectives under each project was achieved with a multidisciplinary team of researchers within the period of implementation of the NARP. Inadequate funding was largely responsible for the inability of the researchers to accomplish all the set objectives

2. ACHIEVEMENTS OF PROGRAMME OBJECTIVES

The achievements of programme objectives are discussed in the sections that follow under summary of research undertaken, the main findings and conclusions, as well as the achievements and impact of the activities. These achievements are presented separately for each of the five broad research areas.

Project Title: PROCESSING AND UTILIZATION OF COWPEA CULTIVARS

Project Code: 06-065

Total Funds: ¢19,554,116.00

Summary of Research done, main findings and conclusions

Sub-project #1: ***Studies on tannin concentrations and protease inhibitory effects of different cultivars of cowpea*** *(Vigna Unguiculata)*

Experimental procedure

Thirteen different cultivars of cowpea obtained from the local markets in Ghana and from the experimental lines of the Ghana Grains Development Project, Crops Research Institute, Kumasi were analyzed for their physical characteristics, proximate composition and tannin content. The inhibition of human and bovine pancreatic trypsin, chymotrypsin and total proteolytic activity by extracts from one local red cowpea variety was studied and the thermal lability of the inhibitors was assessed.

Main findings

Tannin content of the cowpea seeds ranged from 0.24 to 6.88 mg CE/g sample. The lowest tannin contents of 0.24 - 0.34 mg CE/g were observed in the cream-coloured *Local blackeye*, *A-11Y1*, *IT87D-16-27*, *IT87D-19-51* and *Bengpala* varieties, while the greatest concentrations of tannin were observed in the *local mottled*, the light brown *Soronko*, *light brown local* and the *maroon-red local* cultivars (3.26, 3.77, 4.20 and 6.88 mg CE/g sample respectively). The *CR-*

06-07 cultivar, though dark brown in colour, had relatively low tannin content of 0.93 mg CE/g. The other cultivars studied, including *Asontem*, *TVX-4678-03E* and *IT87D-10-10* had tannin concentrations ranging between 1.43 and 2.40 mg CE/g sample. The seed coats of these cultivars were either maroon or brown. In terms of enzyme inhibitory activities, cowpea inhibition of proteolytic activity was influenced by the type and source of pancreatic enzymes. At all levels of raw cowpea extract concentration, bovine trypsin was inhibited to a significantly greater extent ($P < 0.05$) than was human trypsin. The most drastic inhibitory effects of raw cowpea was however, observed in N-benzoyl-L-tyrosine-ethylester (BTEE) hydrolytic systems containing human chymotrypsin. The action of cowpea inhibitors was less pronounced (maximum of 50% inhibition) on total proteolytic activity compared to individual inhibitions of trypsin and chymotrypsin. With regards to processing effects, almost complete inactivation of inhibitors was achieved by cooking whole cowpea seeds after soaking and dehulling, while only partial inactivation occurred when raw cowpea was milled into flour before cooking. Effective control of the inhibitory activities in cowpea for maximum nutritional benefits can therefore be achieved by soaking, dehulling and cooking whole cowpea seeds.

Conclusion

The study has clearly demonstrated that commercial cowpea varieties in Ghana have a wide range of tannin content with the highly pigmented cultivars having the greatest concentrations of condensed tannins, especially in the seed coats. Other anti-nutritional factors in the red cultivars include high concentrations of inhibitors of mainly trypsin and chymotrypsin. These inhibitors, the activities of which are selective in terms of type and source of enzyme, can however, be completely destroyed by dehulling and cooking whole seeds for 45 min after soaking.

Sub-project #2: ***Cultivar and processing effects on pasting characteristics, tannin content and protein quality and digestibility of cowpea***

Experimental procedure

Several samples of four local cultivars of cowpea *(Vigna unguiculata)* with distinctly different seed coat colours were evaluated for the effects of roasting and dehulling on the amylograph

pasting characteristics, condensed tannin content, *in vitro* protein digestibility and *Tetrahymena* protein efficiency ratio (*t*-PER). The blackeye type, light brown, mottled brown and the bright maroon-red cultivars were chosen for this study based on popularity and selective preference of consumers for preparation of traditional cowpea foods in West Africa. Whole and dehulled cowpea flours were prepared from raw and roasted cowpeas by grinding in an Ultra-Centrifugal mill equipped with a 0.2mm mesh sieve. The beans were roasted prior to dehulling and/or milling in a hot air oven at 150°C for 35 min. Dehulling was achieved by breaking whole seeds in a laboratory-size disc attrition mill, winowing and separating the seed coats and embryo from the cotyledons.

Flours from each of the cowpea cultivars were analyzed for tannin content following the vanillin-HCl method of Price *et al.* (1978) and applying blank corrections. A reference standard curve was prepared with catechin (+) (Sigma Chemical Co., St. Louis, MO) using concentrations of 0.0 - 0.4 mg/ml and extrapolating to greater concentrations. The tannin content of flours was expressed in terms of catechin equivalents. *In vitro* protein digestibility of cowpea fours was determined by the multi-enzyme method of Hsu *et al.* (1977). The enzymes used were porcine pancreatic trypsin Type IX with 17,700 BAEE units per milligram protein; bovine pancreatic chymotrypsin Type II with 55 units per milligram protein; and porcine intestinal peptidase Grade III with 50 units per gram powder (Sigma Chemical Company, St. Louis, MO).

Protein content of the flours was determined using the FP-428 automatic nitrogen determinator equipped with a thermal conductivity detector (FP-428 Nitrogen Determinator System 601-700-300, version 1.0, Leco Corporation, St. Joseph, MI). The pH of the aqueous suspension of the flour after digestion from pH 8.0 for 10 min was used to calculate protein digestibility according to the regression equation (Hsu *et al.*, 1977). Amylograph pasting viscosity characteristics of the flours were determined with the Brabender VISCO/amylo/GRAPH equipped with a 700 cm-g sensitivity cartridge. For the amino acid analysis, the flours were digested under vacuum with 6N HCl in sealed ampules at 110°C for 24h. The hydrolysates were analyzed for amino acids on a Beckman 121 Automatic amino Acid Analyser.

Main findings

The results of the study have established the relative suitability of the local commercial cultivars of cowpea for weaning food formulation with regards to their physico-chemical characteristics, functionality, nutritive value and content and distribution of tannins. Roasting and dehulling have also been identified as effective means of reducing the adverse effects that limit utilization of some cowpea cultivars. There were wide variations in the hot paste viscosity characteristics of the different cultivars studied. The raw cowpea flour samples exhibited maximum paste viscosities ranging between 260 Brabender Units (BU) for the mottled cultivar and 460 BU for the cream-colored blackeye cultivar. Cowpea cultivars with the greatest peak viscosities showed low stabilities to extended cooking. Extended cooking resulted in low paste stability and there was little retrogradation on cooling. Roasting depressed paste viscosity properties of cowpeas, but when substituted at 20%, the Blackeye cultivar was found to exhibit minimum depressive effects on maize flour pasting properties. All the cultivars studied had similar amino acid profile with high levels of most of the essential amino acids. Tannin concentrations were 0.3 - 6.9 and 7.2 - 116 mg CE/g flour from whole cowpea seeds and seed coats respectively, increasing with intensity of seed colour.

Although dehulling removed 98% of the tannin content of raw cowpea cultivars, improvement in protein quality as a result of dehulling was observed for only the highly-pigmented Maroon-red variety. Roasting significantly improved digestibility and more than doubled the *t*-PER of all cowpea cultivars studied. Roasting depressed paste viscosity properties of all the cowpea cultivars studied. Tannin concentrations were 0.3 - 6.9 and 7.2 - 116 mg CE/g flour from whole cowpea seeds and seed coats respectively, increasing with intensity of seed colour.

Conclusion

The functional and nutritional characteristics of cowpea are significantly influenced by the type of cultivar and processing techniques applied. Roasted cowpeas possess adequate nutritional and functional qualities as protein supplements in cereal-based weaning foods. However, dehulling is necessary to enhance the nutritional quality of the highly pigmented cultivars of cowpea.

Sub-project #3: ***Optimization of extrusion variables for the production of cowpea-based high protein weaning foods***

Experimental procedure

Studies were conducted to establish optimum extrusion parameters for the commercial production of high protein foods from blends of cowpea, maize and peanuts. The effects of extrusion variables on the ease of extrusion and extrudate quality characteristics were determined for blends containing 20% and 30% cowpea. Extrusion variables investigated were extrusion temperature, feed moisture content and feed particle size.

Main findings

For both levels of cowpea in the blend, temperatures below 65°C produced extrudates with high moisture content, large bulk densities, and low expansion index. The products extruded at the low temperatures were firm in texture and required great force for penetration. Higher extrusion temperatures caused a reduction in the hardness and moisture content of the product while increasing the expansion index with a corresponding lowering of the bulk density. Production of nicely puffed extrudates was achieved with extrusion temperatures of 80 - 95 °C and feed moisture content of 15 - 18.5 %. The products obtained with these parameters had moisture content of 9 - 10 % with bulk densities of 230 - 280 Kg/L and product hardness of 10 - 18 Kg maximum penetration force. Feed particle size of less than 500 μm was also found to be ideal in terms of ease of extrusion and product quality characteristics. From the findings of the study, the optimal extrusion parameters for the commercial production of the cowpea-based weaning food by extrusion cooking have been established as follows: (1) blend composition of 20 - 30 % cowpea, 60 - 70 % maize and 10% peanut; (2) feed particle size of 250 - 500 μm for maximum ease of extrusion; (3) extrusion temperature range of 80 - 90 °C; and (4) feed moisture content of 15 - 18 %.

Conclusion

In conclusion, the study has established the effects of extrusion variables on the ease of extrusion and the quality characteristics of extrudates produced from blends of cowpea, maize and peanut

in the production of a high protein-energy food. Increasing extrusion temperatures decreases extrudate moisture content and bulk density while increasing the expansion index. As far as extrusion of the cowpea, maize and peanut composite blend is concerned, feed moisture content is one other critical factor affecting product moisture content, bulk density, hardness and expansion index. Product moisture content increases progressively with increasing water flow rate (and hence, increasing feed moisture content). Increasing the feed moisture content also increases bulk density and causes a decrease in the expansion and firmness of extrudates.

Achievements and impact of cowpea utilization studies

1. The studies have identified cowpea varieties that have high anti-nutritional factors which affect their effective utilization for infant nutrition. The information was made available to cowpea breeders and agronomists in the NARP legumes network to help in the selection of suitable cultivars to be released. Also the nationwide weanimix promotional campaign by the Nutrition Division of the Ministry of health has now been redirected to focus on the promotion of safe cultivars of cowpea for maximum nutritional benefits.

2. The basis for selection of commercial varieties of cowpea for specific food uses has been established. Development of appropriate processing methods for the reduction of anti-nutritional factors in cowpea has also enhanced its industrial utilization as an inexpensive protein base for fortification purposes. Small-scale local entrepreneurs have been assisted through the cowpea research efforts at the Food Research Institute in the establishment of factories to process cowpea-based high protein weaning foods. The studies have also contributed to global knowledge in legume processing and utilization through the publication of a scientific paper on the findings (Plahar, W.A., Annan, N.T. and Nti, C.A. 1997. Cultivar and processing effects on the pasting characteristics, tannin content and protein quality and digestibility of cowpea. *Plant Foods for Human Nutrition* **51**:343-356)

3. An improved extrusion technology has been successfully developed and is available for the commercial production of high protein-energy food based on local raw materials. The

potential impact on import substitution for Government, economic benefits to cowpea farmers and nutritional status of the average Ghanaian, is quite obvious.

Project Title: SOYBEAN PROCESSING AND UTILIZATION STUDIES

Project Code: 06-046

Total Funds: ¢28,151,776.00

Summary of Research done, main findings and conclusions

Sub-project #1: ***Evaluation of soybean cultivars for traditional food uses in Ghana: Varietal effects on quality characteristics of soymilk and full-fat soy flour extracts***

Experimental procedure

Five cultivars of soybean that are being promoted for cultivation in Ghana were analyzed for their physical, chemical and functional characteristics. A complete evaluation of the cultivars was undertaken for the influence of the physical characteristics, chemical composition and trypsin inhibitor activities on the quality and acceptability of soymilk and full-fat soy flour extracts. The five cultivars of soybeans studied include *Anidaso, Bengbie, Salintuya #1, Salintuya #2* and *Nakpanduri* which were received from the experimental lines of the Crops Research Institute under the NARP Soybean Research Project.

Main findings

The largest hull content of seeds was recorded for the *Nakpanduri* cultivar (11.43%), followed by *Salintuya #2* (10.68%), *Bengbie* (9.49%), *Salintuya #1* (9.05%) and *Anidaso* (8.11%). *Nakpanduri* also recorded the highest test weight value of 75 Kg/hL with values for the other cultivars ranging between 69 and 71.5 Kg/hL. Values for 1000 seed weight were lowest (70.28g) for *Nakpanduri* seeds which were also physically small in size. Although *Anidaso* had a similar

test weight as *Bengbie*, its 1000 seed weight (138.4g) was significantly higher ($P \geq 0.05$) than for the other cultivars studied. *Bengbie* and *Salintuya #1* had similar 1000 seed weights of about 110g which was significantly lower than that for *Salintuya #2*. Initial water absorption rates and maximum absorption capacities were different among the cultivars, depending mainly on the seed coat component and seed size. *Nakpanduri*, with the thickest seed coat, gave the slowest initial rate of absorption and achieved maximum absorption within the longest period of 24h. *Salintuya #1* and *#2* produced the fastest and the same initial rate of absorption (about 56g/100g/h), but the two cultivars were quite different in their water absorption capacities. *Salintuya #2* exhibited the largest absorption capacity of 145g/100g while *Salintuya #1* was among the least with a capacity of 128g/100g solids. Protein content of the cultivars ranged between 41 - 48 % with the highest content observed in *Nakpanduri*, followed by *Anidaso* and *Salintuya #1* (46%), *Bengbie* (44%) and *Salintuya #2* having the least value of 41%. Typical of most legumes, cultivars with lower protein content gave higher fat content values and vice versa. Fat content of the cultivars ranged between 16.9% for *Nakpanduri* to 21.7% for *Salintuya #2*.

In terms of product development some of the soybean cultivars studied produced good quality and acceptable soybean milk by a simple hot water extraction technique. Except for *Nakpanduri* and *Bengbie*, soymilk samples produced from the different soybean cultivars possessed good sensory characteristics in terms of colour, aroma, taste, mouthfeel and overall acceptability. Soymilk samples from *Nakpanduri* and *Bengbie* were found to be darker and had slight beany aftertaste. The best cultivars for soymilk production were *Salintuya #1* and *Salintuya #2*. For full-fat soy flour production, all five cultivars were found suitable for the extraction of high quality and acceptable flour with insignificant levels of trypsin activities. However, in terms of ease of processing, the relatively small *Nakpanduri* seeds were found to be difficult to dehull.

Conclusion

Varietal differences do exist in the physical properties, chemical composition and functional characteristics among the following five cultivars of soybeans studied: *Anidaso, Bengbie, Salintuya #1, Salintuya #2* and *Nakpanduri*. Initial water absorption rates and maximum

absorption capacities differ among the different soy varieties, depending mainly on the seed coat component and seed size. In terms of product development, the best cultivars for the production of good quality and acceptable soybean milk by a simple hot water extraction technique are *Salintuya #1* and *Salintuya #2*.

Sub-project #2: ***Evaluation of soy-fortification of Ghanaian traditional foods: Household preferences for mode of soy-fortification and the effect on some process characteristics***

Experimental procedure

Studies were conducted to determine the preferred mode of soy fortification in terms of soy products used and the traditional dishes targeted in selected towns and villages in the Greater Accra Region. Studies were also conducted to develop an appropriate household/small-scale enterprise level technique for the production of soy-fortified fermented maize dough (or meal) by comparing different treatments, processing methods and fortification levels. The effects of fortification method of the Ghanaian traditional fermented maize dough with raw or heat-treated whole soybeans and full-fat soyflour at 0%, 10% and 20% replacement levels, on the rate of fermentation and product quality were investigated. Sensory characteristics, trypsin inhibitor activity, amino acid pattern, proximate composition and hot paste viscosity were used as the indices of quality.

Main findings

The most preferred soy product for fortification was found to be soy flour followed by soybean paste and soy grits in that order. Traditional foods for which fortification is most desired was found to be cereal based weaning foods (fermented maize dough and Tom brown), stews and soups (including leafy vegetable stews, ordinary vegetable stews, palm soup and groundnut soup), banku and gari. With regards to the effect of soy fortification of fermented maize dough on the process characteristics and product quality, addition of whole soybeans to maize before milling and fermentation reduced the fermentation time by 60% while increasing the protein

content by 24% and 70% respectively for 10% and 20% levels of fortification. A significant improvement was also achieved in the amino acids pattern of the fortified dough. However, raw whole soybeans imparted an undesirable color and beany flavor and an appreciable concentration of trypsin inhibitor activity (TIA) to the dough. Boiling soybeans for 20 min before incorporation into the maize for milling and fermentation was found necessary for desirable flavor and low levels of TIA. Little or no changes in the pasting viscosity characteristics occurred in samples containing boiled soybeans, while the usual method of fortifying maize meal with soy flour was found to severely depress the pasting viscosity characteristics and drastically reduced the acidity of the fermented dough. Based on the findings of the study, the most appropriate technique for the production of soy-fortified high protein fermented maize dough has been suggested to involve incorporation of boiled whole soybeans in soaked maize before milling and fermentation for improved sensory characteristics, enhanced nutritive value and optimal functional properties.

Conclusion

Soy flour and soybean paste are the most convenient and accepted forms in which traditional food uses of soybeans can be applied. However, for intermediate semi-commercial products such as maize dough, addition of boiled whole soybeans to soaked maize before milling and spontaneous fermentation is the most appropriate technique for the preparation of soy-fortified fermented maize dough, which minimizes the drudgery involved in soybean processing while achieving good nutritional quality. The procedure also causes a drastic reduction in fermentation time without the need for the use of starter cultures.

Sub-project #3: ***Production and quality characteristics of flavoured soybean milk and a dehydrated high-protein meal developed from the residual by-product.***

Experimental procedure

The sensory quality characteristics of four flavoured soymilk samples, including vanilla, banana, coffee and chocolate, were evaluated at varying concentrations of the flavour in order to establish the most acceptable flavour and the desired concentration for commercial production of soymilk.

A process was also developed for the utilization of the residual by-product of soymilk production as a stable high-protein food for use in Ghanaian dishes and for fortification purposes. Hot extraction of the `milk' from blanched and dehulled soybeans was achieved by blending in hot water and sieving through muslim cloth. This yielded the milk and a wet residue which was dried at 70°C - 80°C to obtain the relatively shelf-stable dehydrated meal. A comprehensive quality assessment was undertaken to evaluate the quality characteristics of the unflavoured milk extract as well as the wet and the dehydrated meal products. Product quality factors determined include the proximate composition, minerals (sodium, potassium, calcium, magnesium, phosphorus, iron, manganese, zinc and copper), vitamins (total pyridoxamine, riboflavin and biotin), selected mono- and di-saccharides (fructose, sucrose and maltose), amino acids and trypsin inhibitor activity. The nutritional and biochemical quality of the dehydrated residual meal was also evaluated in animal studies.

Main findings

Addition of flavours was found to improve the sensory characteristics of soymilk. Taste, aroma, mouthfeel and hence overall acceptability of the soymilk samples were improved significantly by addition of coffee, vanilla, banana or chocolate flavours. The maximum concentrations of the individual flavours for optimal sensory impact were established. The milk extraction procedure was able to extract only a small proportion of the protein from the raw seeds, leaving the dried residue with about 36% protein content. The concentration of individual amino acids was similar to (but in some cases greater than) in the whole soybean. Lysine remained high in both the wet and the dehydrated product (6.47 - 6.57 g/16g N). With the B-vitamins, more than 60% of the original content in the beans was extracted with the milk. Contrary to this observation, high proportions of the minerals determined were found to be retained in the residue during soymilk extraction. The heat treatment was found adequate in reducing the trypsin inhibitor levels in the dehydrated residue from 25 mg/g to minimal levels of 1.5 mg/g. A blend containing 20% of the dehydrated meal in roasted maize flour was found to have a protein content of 15.6% with a protein efficiency ratio (PER) of 2.1 (casein control PER = 2.5). There were no adverse biochemical or histopathological effects as determined in animal studies.

Conclusion

The study has been able to establish the need to add flavour to soymilk to enhance the desirable nutritional attributes. Vanilla, coffee, banana and chocolate flavours can serve as effective materials for improving the taste, aroma, mouthfeel and overall acceptability of soymilk. In addition, vanilla improves the colour of the product. The residual by-product of the milk extraction when dehydrated is a stable highly nutritious product for use as a protein supplement in Ghanaian dishes, including cereal based weaning foods. The scope of utilization of the residual product could be widened to include several traditional foods, bakery products, weaning foods, etc. There is however the need to develop appropriate recipes and large-scale consumer acceptability tests.

Sub-project #4: ***Extension activities under the soybean utilization project***

Experimental procedure

Training programmes and field demonstrations were undertaken to extend the technology for the preparation of soy-gari to commercial gari processors at Korle-man and Manchie: two farming communities in the Greater Accra Region of Ghana. This activity was undertaken under the NARP legumes utilization programme to support activities being sponsored by the IDRC/IITA soybean utilization project in the two villages. A post-adoption and impact assessment survey was carried out four years after the introduction of the technology to assess the rate and scale of adoption as well as the socio-economic impact.

Main findings

Adoption rate of the soy-gari processing technology was found to be 100% in the two villages, with a fast diffusion of the technology to other areas. Assessment of the scale of adoption also showed 100% full adoption with no modifications to the original procedure introduced.

Conclusion

The extension of the soy-gari production was highly successful in the two cassava processing

communities. The demand for the product is also quite high, and this is the main factor motivating the fast diffusion of the technology.

Achievements and impact of studies under the soybean project

1. Varietal characterization of soybean cultivars was achieved, and the results were made available to the Crops Research Institute of the C.S.I.R. for selection of best cultivars for promotion taking into consideration all factors related to the agronomic, processing and utilization aspects. The expected impact is increased production and utilization of soybean for improved socio-economic and nutritional benefits.

2. The most convenient and most preferred mode of soybean utilization in traditional foods have been established for use in soybean promotional activities in the Ghanaian communities for an effective impact.

3. A technology developed for the production of soy-fortified fermented maize meal has not only served as a convenient method for household preparation of an enriched dough, but has also been taken up by entrepreneurs for the production of the meal which is now available on the Ghanaian local markets as a convenience intermediate meal for use in the preparation of various dishes.

4. In addition to developing techniques to enhance the acceptability of soymilk, the studies have also established a procedure for a 100% utilization of soybeans without any by-product waste in order to derive maximum economic and nutritional benefits.

5. Through the activities of the soybean project, the production of soy-gari has now become a major commercial activity in two pilot villages in the southern sector of the country. The beneficial effects on the nutritional status and the socio-economic benefits of the people in cassava processing areas have been favourably acknowledged. Processors claim an increase in income generated by adding value to the traditional gari through the incorporation of the soybean.

Project Title: PRODUCT DEVELOPMENT BASED ON BAMBARA GROUNDNUT

Project Code: 06-066

Total Funds: ¢ 5,714,474.00

Summary of Research done, main findings and conclusions

Sub-project #1: ***Bambara flour preparation and formulation trials***

Experimental procedure

Samples of bambara flour were prepared from raw, roasted and boiled, dried and dehulled bambara to obtain three treatment samples. The effects of the treatments on the proximate composition and performance in bakery products and fried snacks, were assessed. Bakery products tested were cakes and cookies in which the bambara flours were substituted for wheat flour at 30, 40 and 50 % replacement levels. The same levels of bambara flour substitution were used to determine the performance of the bambara in the preparation of fried snacks such as doughnut.

Main findings

Although dehulling of the bambara was found to be a relatively difficult process, it was necessary to enhance the protein content of the flour. The cakes and cookies prepared with bambara flours had similar dough handling properties like the wheat flour control samples. Acceptability of the products containing up to 50% bambara flour was similar to that of 100% wheat flour samples. Taste panelists detected beany flavour at substitution levels beyond 50%.

Conclusion

The formulation trials showed that bambara flour can be a good supplement for wheat flour in the preparation of cakes and cookies.

Sub-project #2: ***Utilization of bambara flour in Akla preparation***

Experimental procedure

Formulation trials were conducted using bambara flours for the preparation of a popular fried bean paste. Traditionally, cowpea flour is used to prepare the fried bean paste, akla - a snack food. In preliminary studies a series of trials were performed for selection of speed and time for whipping of bambara flour and water mixture into a batter of good specific gravity. A mixture of 100g bambara flour and 120 ml water was found ideal to produce a batter of similar consistency to cowpea batter for akla preparation. The whipped paste was seasoned with onions, ginger, salt and was deep fried in oil. The fried bambara akla was assessed for its sensory attributes relative to cowpea akla.

Main findings

The bambara flour was found to possess good foaming capacity, producing akla with desirable spongy texture and taste. The sponginess, moistness, aroma and taste of the bambara akla were moderately acceptable by taste panelists. Results of triangle difference tests showed significant differences in the sensory characteristics of bambara and cowpea akla samples, with the latter having slightly higher acceptability scores.

Conclusion

Raw bambara flour can be used for the preparation of acceptable akla in place of cowpea flour.

Sub-project #3: ***Varietal characterization and product development for the diversified food uses of bambara groundnut (Voandzea subterranea)***

Experimental procedure

Three varieties of bambara groundnut with distinct colour differences were evaluated for their physical, chemical and functional characteristics, as well as their relative acceptability for specific food uses. A processing technique was developed for the preparation of bambara flour samples

which were assessed for their suitability for diversified food uses including bakery products and fried snack foods.

Main findings

The cream blackeye variety of bambara had the thinnest seedcoat which facilitated the fastest rate of water absorption, reaching a maximum capacity of 104g water/100g solids within 60 h. The black white-eye and maroon white-eye varieties on the other hand had relatively thicker seedcoat not significantly different ($p > 0.05$) from each other resulting in slower water absorption rates but higher water absorption capacities. In terms of chemical composition, the black variety had the highest protein with the lowest fat content. A tannin content of 13.5 mg CE/g sample recorded for this variety was found to be about 3-fold that of the cream (4.1 mg CE/g) and the maroon (5.4 mg CE/g) varieties. In the traditional preparation of *Aboboe*, (boiled bambara with added spices), the cream and the maroon varieties were preferred over the black variety which scored relatively low for texture and appearance. Hot paste viscosity studies on raw bambara flour samples showed significantly ($p < 0.05$) lower peak values, longer gelatinization times but greater paste stability in comparison to cowpea flour. Among the varieties studied, the black and maroon coloured ones showed lower paste viscosities than the cream. A comparison of the cream black-eye bambara flour with cream black-eye cowpea flour in the preparation of *Akla* (a popular fried bean paste snack) showed only a slightly higher preference for the cowpea *Akla* for most of the sensory attributes, except texture. *Akla* from bambara was heavier and less spongy. In the preparation of cakes, cookies and doughnuts, 20% substitution of bambara flour was found to be most acceptable, while beany flavours were detected at 50% replacement levels.

Conclusion

Varietal differences exist in the physical, chemical and functional characteristics of bambara groundnuts studied. Darker coloured seeds have thicker seedcoats resulting in low water absorption rates and higher tannin contents. The bambara flours had low hot paste viscosities in comparison to cowpea flours. Bambara flours possess quality characteristics that make them suitable for use as intermediate products in composite flours for bakery goods. There is the need to develop and evaluate more products and recipes for enhanced utilization of the Bambara.

Achievements and impact of studies under the bambara project

The studies on bambara have been able to characterize popular varieties of bambara in local Ghanaian markets in terms of their physical characteristics, water absorption properties, chemical composition, hot paste viscosities, and sensory properties for the purpose of developing convenience intermediate products for diversified food uses and to evaluate recipes based on bambara products. This in addition to the product development activities undertaken, has helped to enhance the utilization of the bambara groundnut in Ghana.

Project Title: DESIGN AND CONSTRUCTION OF CLEANING MACHINES FOR LEGUMES

Project Code: 06-015

Total Funds: ¢ 5,377,035.00

Summary of Research done, main findings and conclusions

Sub-project #1: ***Studies on existing cleaning, sorting and grading machines***

Experimental procedure

Surveys were conducted using pre-tested questionnaires to determine the traditional methods and existing machinery used for cleaning, sorting and grading grains and legumes in Ghana. The target population included small and medium scale producers and market retailers, large scale commercial farmers, governmental and other marketing agencies including Ministry of Agriculture, Food Distribution Corporation, Ejura farms Ltd. etc within the major maize and cowpea growing areas in the Greater Accra and Volta Regions of Ghana.

Main findings

Respondent farmers indicated that they harvest and shell maize and cowpea manually, after which

they are cleaned by winnowing and hand picking. No sorting or grading is done at the farm level. Middle men who purchase from the farmers in lots of 50 - 200 bags maize or 10 - 70 bags cowpea do not usually clean or sort. In cases where further cleaning had to be done, hired labour is used to winnow and hand pick. Market retailers procure their grains at a rate of 5 - 10 bags a week and retail in 50 Kg or 2.5 Kg portions. Market retailers clean their stock by sieving through wire or cane sieves, and occasionally by hand-picking foreign materials such as stones and broken corn cobs.

Conclusion

On the basis of the results obtained from the survey, two main capacity groups: 0-10 bags per day and 10-40 bags per day were identified and selected for the design of the cleaning and grading machine.

Sub-project #2: ***Design, construction and evaluation of cleaning, sorting and grading machines for maize and cowpea***

Experimental procedure

Based on the surveys conducted in the first study, a 500 Kg/hr capacity machine was designed and constructed. The design criteria included material selection, sizing of component parts, choice of standard parts, ease of operation, ease of maintenance, and ease of disassembly and assembly. The machine was designed with three major cleaning/grading features for quality cleaning and precision size grading. These features include scalping, aspiration, and separation or grading.

Main findings

The scalping reel effectively rejected larger particles such as broken cobs, twigs, bones, pebbles, stones etc from entering the machine. The aspirator fan served to create a stream of suction through the product to suck out all lighter particles, chaffs, dusts etc from the product. The grading/separator also removed all particles smaller than the normal size of maize or cowpea

(such as immature seeds, broken kernels etc.). The general design specifications of the machine were as follows: length - 152 cm, width - 76 cm, and height - 150.5 cm. It has a capacity of 500 Kg/h and a power requirement of 1.5 to 2.0 HP electric motor.

Conclusion

The machine designed and constructed is for the medium scale producers and marketing agencies with high bulk grain handling. It would be necessary to survey more areas of the country to assess all capacity ranges for an effective design of such machines for the small scale producers and market retailers with very low handling capacities.

Achievements and impact of studies under the machine fabrication project

The most significant achievement is the availability of a machine that could be used to add value to the locally produced grains and legumes.

Project Title: ADAPTATION/MODIFICATION OF WINGED BEAN DEHULLING PLANT FOR COWPEA, GROUNDNUT AND SOYBEAN

Project Code: 06-001

Total Funds: ¢ 6,379,335.00

Summary of Research done, main findings and conclusions

Experimental procedure

The need to utilize under-utilized facility at the Food Research Institute (FRI) for much needed and ever growing demand for affordable and cost effective legume processing machinery resulted in the formulation of the study which seeks to modify and adapt the Winged Bean Dehulling Plant (WBDP) to process legumes such as soybean, groundnut and cowpea. The winged bean dehulling plant consists of the following units: bucket elevators (6No.), grader/aspirator, oil mixing machine, splitter and splits separating machine. Others are conditioning units (2No.), dehulling machine and husk separator/aspirator. The WBDP was test run with soybean, roasted groundnut and cowpea to select the units that could clean and dehull them. The grader/aspirator, the splitter and two bucket elevators were selected for modification and adaptation after the test run. Factors that influenced the modification include the sizes and geometry of the three commodities and the need to improve on individual machine performance and the modified plant as a whole. The elevator basically consists of a lower compartment, a pair of trunkings and an upper compartment with an electric motor. In the lower compartment of each elevator, a three-sided metal sheet is welded to the sides of the compartment and it is positioned about 20 mm below the lowest position of the buckets from the trunkings. The rear side of the lower compartment is hinged so that it can be opened for repair and maintenance work and closed when operational. The two elevators have been installed at different positions with their respective outlet chutes directed into the hoppers of the grader/aspirator and the dehuller.

The grader/aspirator consists of a hopper with a feed regulator, a blower with housing and a rectangular box with two screens and three outlet chutes. The feed regulator is a wooden piece

with a square cross-sectional area whose length just fits the inner dimensions of the hopper with about 3 mm allowance at each end. The two ends of this wooden piece are supported at the centres by two separate shafts whose bearings are bolted to the frame of the machine. The feed regulator is driven by a pulley system ensuring a reduced speed. The housing of the blower contains two directional trays which direct materials to flow in opposite direction to the air flow and also ensuring considerable air - material contact time to guarantee effective cleaning.

The splitter has been converted into a dehuller by the introduction of a separating chamber at he outlet chute and an air blower system which supplies air across the direction of the material flow. The separating chamber consists of an air inlet, material inlet, dehulled material outlet chute, air-husk outlet chute and a central separating area. The blower system consists of a blower installed on a metal stand bolted to the floor close to the electric motor, a pulley - shaft - bearing system responsible for transferring the motor's output to the blower and cylindrical trunks for transporting air from the blower to the separating chamber. The husk and dehulled materials pass through the material inlet chute to enter the separating chamber where they experience a mass of air perpendicular to their direction of flow. Due to its relatively lighter weight, the husk blown by the air through the air - husk outlet chute into a husk collecting bin while dehulled materials, not affected by the air, fall through the material outlet chute to a product receptacle.

A central electrical control panel has been designed and constructed for the above-mentioned machines which are expected to work simultaneously. The central panel is served by a 4 x 6 mm^2 flexible cable and accommodates four main witches and four starters connected to their respective electric motors with 4 x 2.5 mm^2 flexible cable. It is installed on a wall at a convenient position for the operator.

Main findings

Two elevators and a grader/aspirator have been modified and a splitter has been converted into a dehuller and all have been installed for continuous operation. Preliminary test runs have shown that the modified plant is capable of cleaning and dehulling soybean and roasted groundnut. It is also capable of cleaning cowpea but not dehulling it. The quality of materials left in the lower

compartment of the two bucket elevators has been reduced by 66% by design. The flow of materials from the hopper of the grader-aspirator to the cleaning chamber and the grading sieves has been regulated by the introduction of a feed regulator. Also cleaning of materials has improved due to the increase in air - material contact time. In addition, the splitter has been converted into a dehuller. The end result is the availability of processing machinery to clean and grade soybean, cowpea and groundnut and to dehull soybean and roasted groundnut with complete engineering drawings, technical specifications and data that will benefit food processors and manufacturers of food processing machinery and equipment.

Conclusion

The winged bean dehulling plant has been successfully modified to effectively handle the cleaning and grading of soybean, cowpea and groundnut, as well as to dehull soybean and groundnut.

Achievements and impact of studies under the Winged Bean Plant modification project

The modification/adaptation of the Winged bean dehulling plant has maximized its scope of utilization and has facilitated increased volume of processed legumes for traditional food uses. Also there is the possible impact of increase in income of affected food processors and equipment manufacturers.

with a square cross-sectional area whose length just fits the inner dimensions of the hopper with about 3 mm allowance at each end. The two ends of this wooden piece are supported at the centres by two separate shafts whose bearings are bolted to the frame of the machine. The feed regulator is driven by a pulley system ensuring a reduced speed. The housing of the blower contains two directional trays which direct materials to flow in opposite direction to the air flow and also ensuring considerable air - material contact time to guarantee effective cleaning.

The splitter has been converted into a dehuller by the introduction of a separating chamber at he outlet chute and an air blower system which supplies air across the direction of the material flow. The separating chamber consists of an air inlet, material inlet, dehulled material outlet chute, air-husk outlet chute and a central separating area. The blower system consists of a blower installed on a metal stand bolted to the floor close to the electric motor, a pulley - shaft - bearing system responsible for transferring the motor's output to the blower and cylindrical trunks for transporting air from the blower to the separating chamber. The husk and dehulled materials pass through the material inlet chute to enter the separating chamber where they experience a mass of air perpendicular to their direction of flow. Due to its relatively lighter weight, the husk blown by the air through the air - husk outlet chute into a husk collecting bin while dehulled materials, not affected by the air, fall through the material outlet chute to a product receptacle.

A central electrical control panel has been designed and constructed for the above-mentioned machines which are expected to work simultaneously. The central panel is served by a 4 x 6 mm^2 flexible cable and accommodates four main witches and four starters connected to their respective electric motors with 4 x 2.5 mm^2 flexible cable. It is installed on a wall at a convenient position for the operator.

Main findings

Two elevators and a grader/aspirator have been modified and a splitter has been converted into a dehuller and all have been installed for continuous operation. Preliminary test runs have shown that the modified plant is capable of cleaning and dehulling soybean and roasted groundnut. It is also capable of cleaning cowpea but not dehulling it. The quality of materials left in the lower

compartment of the two bucket elevators has been reduced by 66% by design. The flow of materials from the hopper of the grader-aspirator to the cleaning chamber and the grading sieves has been regulated by the introduction of a feed regulator. Also cleaning of materials has improved due to the increase in air - material contact time. In addition, the splitter has been converted into a dehuller. The end result is the availability of processing machinery to clean and grade soybean, cowpea and groundnut and to dehull soybean and roasted groundnut with complete engineering drawings, technical specifications and data that will benefit food processors and manufacturers of food processing machinery and equipment.

Conclusion

The winged bean dehulling plant has been successfully modified to effectively handle the cleaning and grading of soybean, cowpea and groundnut, as well as to dehull soybean and groundnut.

Achievements and impact of studies under the Winged Bean Plant modification project

The modification/adaptation of the Winged bean dehulling plant has maximized its scope of utilization and has facilitated increased volume of processed legumes for traditional food uses. Also there is the possible impact of increase in income of affected food processors and equipment manufacturers.

3. MAJOR FACTORS THAT HAVE AFFECTED PROJECT IMPLEMENTATION

a. *Factors not subject to Government control*

For the latter part of 1997 and throughout 1998, the draught situation in the country caused a drastic reduction in the water levels of the Akosombo dam which supplies power to the nation. Consequently, there was serious energy crisis in the country for more than a third of project implementation period. This situation partially affected achievement of project objectives on schedule.

b. *Factors subject to government control*

Late and inadequate release of funds was blamed in part on inadequate provision of counterpart funds by government. The main lesson learnt during the implementation of the project was how to best manage with the inadequate funds received to execute the project.

4. POST-PROJECT ACTIVITIES AND PROGRAMME SUSTAINABILITY

In view of the aforementioned constraints in the implementation of the project, all the objectives of the legumes project could not be achieved within its lifetime, although a number of important areas have been covered and some impact made. A greater impact could be made towards achievement of the set goals if certain follow-up activities are pursued. For example varietal characterization and product development activities, as well as field demonstrations for household utilization of legumes need to be continued and extended to more areas of the country for maximum impact on the national economy through import substitution and on the socio-economic and nutritional status of the population. Also there is the need for introduction of the developed machinery to food processors, farmers, market women and local manufacturers of food processing machines and equipment. This will contribute to increase the volume of processed legume in our traditional diets to enhance their protein quality.

In the short term, proposals have been developed and submitted under the Agricultural Sector Services Improvement Project (AgSSIP). The research and development approach involves not only varietal evaluation and technology development, but also dissemination through training. Training in technology application and adoption has been recognized by the Food Research Institute as one effective means of improved technology transfer to user agencies. Local entrepreneurs, cooperatives, Agricultural extension staff, Health workers etc. need to be trained in developed technologies for effective impact on the target population. Proposals on grain legumes post-harvest research submitted for consideration under the AGSSIP to help sustain research and development activities on grain legumes utilization were still in the following areas:

- Evaluation of improved cultivars to facilitate varietal selection in terms of both agronomic and utilization characteristics.
- Enterprise level technology development (products, processes and appropriate machinery) for specific products.
- Development and promotion of house-hold utilization for improved nutrition
- Development of appropriate machinery for post-harvest handling.