SORGHUM FLOUR SUBSTITUTION FOR WHEAT FLOUR IN SAMBUSA NUTRITIONAL AND PALATABILITY STUDIES

by

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INTRODUCTION

World Food Problem

The existence of hunger and famine is as old as man. The prospects today and for the near future with respect to world food shortages are reaching a state of crisis. The world food problems are internationally recognized today by leaders of government, industry, and enlightened citizens of all countries. A substantial positive effort is now in progress but no one would say that more than a beginning has been made towards curbing the presently widening gap between world food production and population growth.

For Africa, Latin America and South East Asia, where large populations with low incomes prevail, there are poor diets and relatively small potential for increased food production (11, 22). Hunger is prevalent in both large cities and villages. In East Africa, education of villagers and farmers in food production is practised, however, without simultaneous development of transportation, preservation, processing and marketing systems no major long range improvement in the food situation can be made.

The Food and Agriculture Organization (FAO) reported that 60% of the people in developing countries are suffering from malnutrition, defined as an improper nutritional balance in the diet. Food habits vary widely from region to region; food habits have the strength of tradition behind them; even so, it has been estimated (11, 43) that about 70 to 85% of calories consumed in the developing countries are supplied by cereals, starchy roots and sugar. Consequently deficiencies in protein and vitamins are often major problems (22, 38), since those food are not noted for their nutritional quality when they are a major part of the diet. Inadequate protein nutrition is of vital concern since it has direct and indirect effects on both growing children and adults (16, 39). Some of the effects of protein malnutrition include increased propensity to infection, reduced stature, reduced birth weight, poor recovery from surgery, trauma and other pathological states (35).

The Food and Nutrition Board, National Academy of Science - National Research Council of the United States, reported that the segment of the population most severely damaged by malnutrition in nearly all developing countries is in the range from weaning to five years. Because of poor nutrition upto 50% of the children fail to survive to school age. Those who survive suffer permanent stunting equivalent to two or three years of their most rapid growth, and irreversible damage to the central nervous system comparable to the suppression of this growth. Therefore the task of increasing food supplies to provide adequate diets for the human race assumes greater proportions in view of annual population growth rates. A forceful summary on world population growth and the urgency of the situation was given by Brown (10): "At the time of Christ, the world population was numbered about 250 million. This number slowly expanded and by 1600 AD it had doubled to 500 million. By 1900 the annual rate of increase was only one percent. As of 1960, it was estimated at about two percent and expected to be well above this figure for the rest of the century." This will mean that in the remarkably short period of the next third of a century as many new hungry mouths will be added to the world's masses as it took all of man's previous history. However, the current average increase of 2.1% per year is not equally shared by all nations. The true population explosion is occuring mainly in parts of Asia, Africa, the near East, and Latin America where some countries are currently showing population increases approaching 4% per year. These are the areas of greatest starvation today and the broad areas that will constitute 80% of the world's population by the close of the century.

The nature of man's struggle against hunger is evident. The need is clear for changes in agricultural practices, in food processing and technology, and in food habits to provide enough food at a price within the purchasing power of the consumer. The Food and Agriculture Organization (28) has estimated that about 5 to 10% of the world's food grain is lost to insects and other faulty storage practices; 5% representing about 50 million tons lost in countries that are short of food and can least afford the loss. At a per capita consumption rate of 120 kilograms, these losses would be sufficient to feed 400 million extra people. A successful program for improving food quantity and nutrition in general will, undoubtedly, reduce mortality, but will temporarily alleviate the population problem.

Humanitarian considerations dictate that children now alive should be helped to obtain the food suitable for proper growth. It is not enough to merely mention these thoughts. To pursue them in a significant and meaningful way is to give not only comfort and encouragement but also strength to those already engaged in and dedicated to alleviating these problems of food shortages and resultant malnourishment. To this end the studies of Sambusa have been undertaken.

Sambusa and its Traditional Processing Techniques

An attempt is made here to describe the Sambusa in terms of its processing techniques to permit better understanding of the significance of these studies since no concise definition of the product could be given without loss of details by the reader who is unfamiliar with this type of food. Essentially, Sambusa is a type of spiced pie whose crust is made from unleavened wheat dough and whose stuffing may be rice, beans or minced meat or a combination of these. In its first stages of processing all purpose flour bought from a retail shop, Fig. 1, is stick-mixed with enough water (or with fresh eggs) until a dough of moderately stiff consistency is obtained. The dough is then allowed to rest for 20 to 30 minutes during which moisture absorption becomes uniform and the dough attains a definite form and consistency. During the dough resting period, the stuffing (beans usually) is prepared by boiling in round-bottomed iron-pots. Raw onions are sliced. After boiling the beans are flavored to taste with spices and salt and fried in oil with the onions in a separate pot.

The rested dough is then kneaded for a short time and divided and moulded manually into small balls. Each ball is then rolled and flattened as far as it can go without the dough tearing using a wooden pin or a bottle of suitable shape and a wooden board. Flour is sprinkled on the board, pin and dough to prevent the dough from sticking. The flattened dough is hand-shaped into a triangle.

ALL PURPOSE FLOUR FROM MILLS

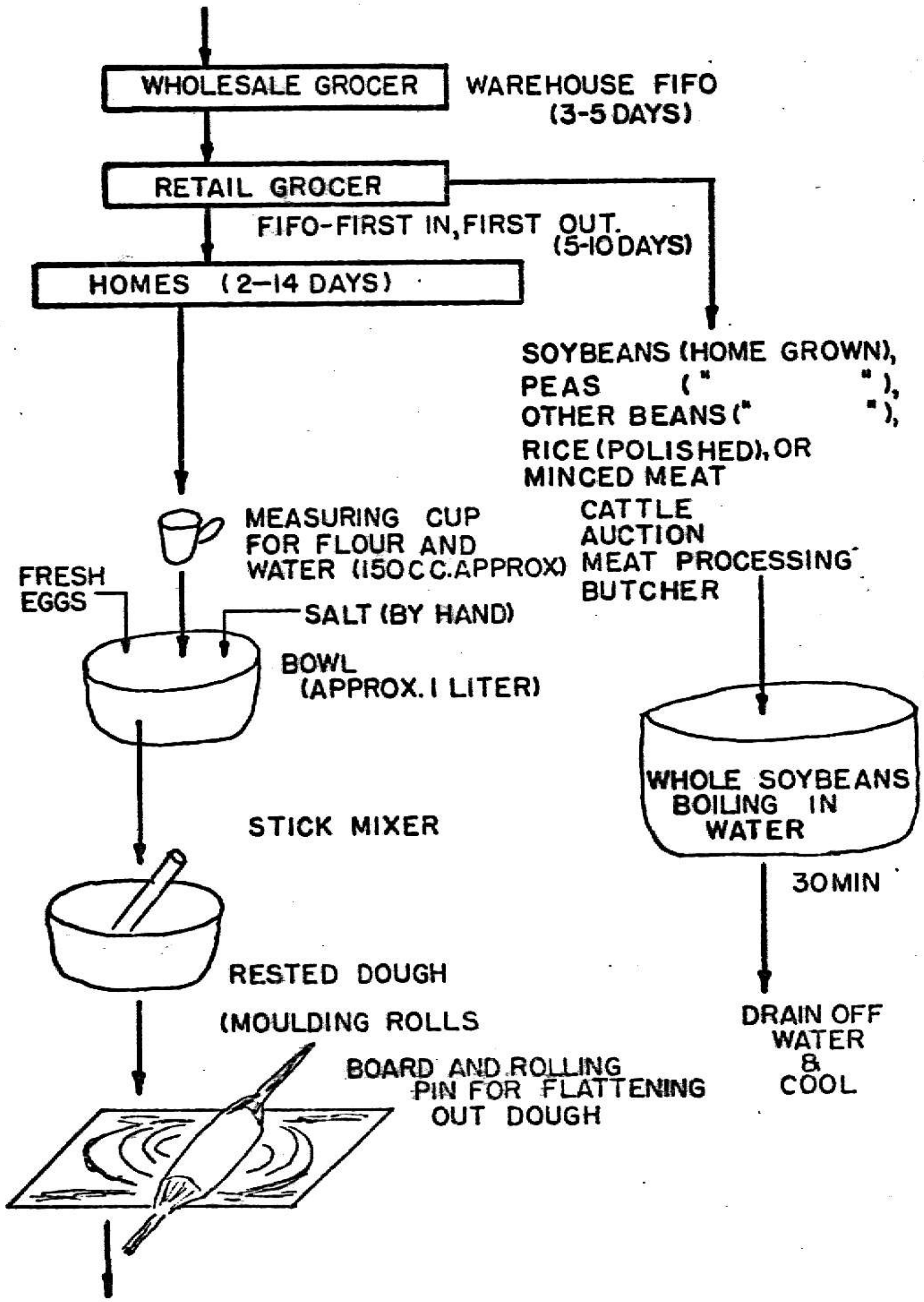


Fig. 1. (a) A Schematic flow for Sambusa processing

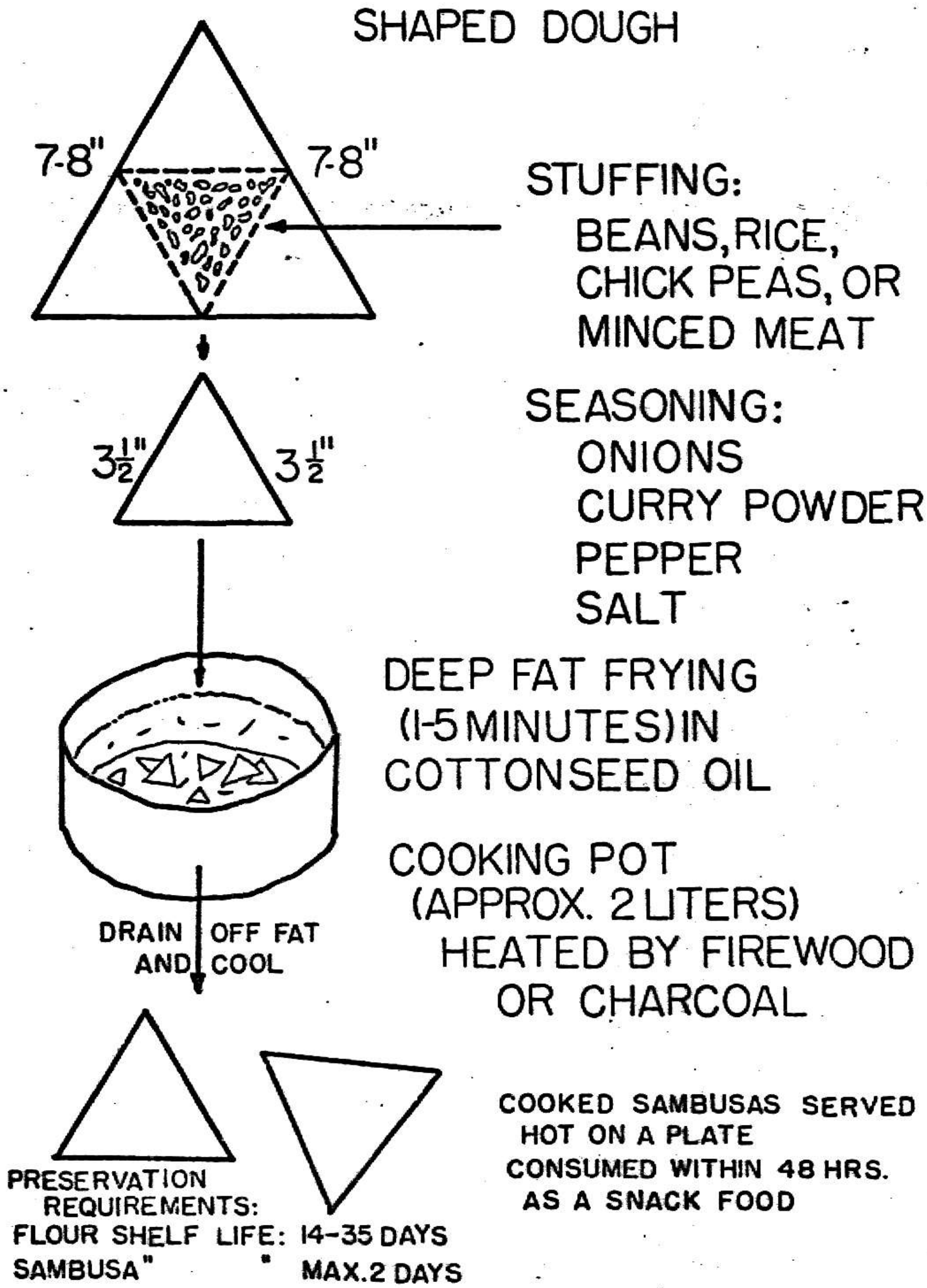


Fig. 1. (b) A schematic flow for Sambusa processing

At this point, appropriate amount of the stuffing is enclosed within the shaped dough. Ten to twenty of these raw Sambusas are transferred to a pot of boiling oil on a red hot glowing charcoal heat. The deep-frying process lasts between 2 to 5 minutes. Due to differences in weight of the Sambusas prepared in this manner, some of them will float. Sambusas are judged to be cooked by the browning reaction on their crusts. To date no form of modern packaging is used at this point. A diagrammatic representation of the methods of the Sambusa processing is shown in Fig.1.

Varieties of the Sambusa

There are several varieties of Sambusa. These varieties are made by the same basic processing techniques and procedures as outlined in Fig. 1. However, the differences depend to a large extent on the type of stuffing and the degree of spicing accomplished. The addition or omission of spices and the type of stuffing used exert pronounced effects on the flavor of the final product. Most varieties of Sambusa have been named according to the type of stuffing. The meat Sambusa (Nyama Sambusa), for example, contains minced meat and is usually the most expensive and most preferred. The bean Sambusa would be intermediate between meat and rice Sambusas in preference. Although marketing conditions, tribal preferences, and cost of stuffing dictate the preponderance of any one of these varieties, one would find all these varieties in any one region of East Africa.

In making rice Sambusa, polished rice is used. The practice is to boil rice in excessive water and when the rice is done, the water is drained off. This practice has serious disadvantages. Vitamins, especially thiamin, are lost in this way. Since thiamin is water-soluble, it will leach out of the rice in proportion to the extent to which it is agitated, and the surface area of the food exposed to water. A desirable method would have to involve preparation that minimizes the length of time the rice is in contact with the water and the use of a minimum of water to reduce cooking losses. As much as 18% of thiamin in rice is reportedly lost in the practice of washing rice several times before cooking (20). Furthermore, a rice Sambusa is basically a wheat-rice combination. These two may be considered a source of incomplete proteins of rather low biological value since both are known to lack one or more of the essential amino acids.

The bean or Soybean Sambusa was the type studied here because it lies between meat and rice Sambusas in preference and cost, and would have good protein quality that is required in East Africa.

The Role of the Sambusa in the East African Diet

The East African taste and diet is varied and difficult to define. However, the foods eaten are predominantly starchy foods, such as cassava, sweet potatoes, corn and cooking bananas. Products made from these include:-

1. Ugali, a product made by mixing corn flour and boiling water until a stiff cooked dough is obtained, is popular in Kenya.

2. Atap is similar to Ugali except millet, sorghum or cassava flour is used, and is popular amongst the Iteso tribe in Uganda.

Ugali and Atap are served with stews that range from a clear seasoned broth to a mixture of several ingredients such as pepper, eggplant, tomatoes, onions, okra and/or other green vegetables and meat, chicken of fish cooked in vegetable oil. Because these products are cheap and have satisfying flavor and appeal, they rank high in the dietary of the families and individuals in the lower socio-economic status.

Whilst the description of these foods are beyond the scope of this research, their brief mention will shed some light on the role and nutritional contribution of the Sambusa. Because of convenience, ease of preparation, and availability the Sambusas are eaten as snack foods accompanied with a cup of coffee for breakfast or a bottle of beer in drinking sessions. In cities and towns, it is not uncommon to find Sambusas, together with a cup of tea, eaten for lunch. For the Moslem community, Sambusas may be eaten with stew, fish or meat with sauce, gravy or other soup preparations. The proportion of Sambusa in the diet depends, to some extent, on the income of the family or individual and the type of Sambusa, with the meat Sambusa being the most expensive. Nonetheless, both the poor and the rich eat it alike.

The State of Dry Sorghum Milling in Uganda

The present status of sorghum milling in Uganda is very simple. Various efforts have been made, especially in towns, to use small mills driven by hand or petrol engines. Three firms, two in Jinja and one in Kampala, grind millet and sorghum on a commercial basis. The total amount of flour is not large; the maximum production by any firm is probably no more than 30 tons of flour each year. In rural areas the method is to pound the grain in a fairly large wooden mortar with a pestle made of heavy wood. This is winnowed in a special tray and the cleaned sample is ground by hand between two flat stones. The work is laborious but produces a very fine flour.

The cash economy of Uganda is increasing and the tendency for the home production of foods, especially those that require much labor, is decreasing. It can be expected that vigorous attempts will be made to produce large quantities of sorghum and millet flour commercially; roller milling may be feasible, but will produce a flour probably more expensive than the flour made in the home. The limitation of the home ground flour is that some method is urgently required by which the keeping qualities of the flour can be improved.

Objectives of the Study

From the foregoing discussions, there is great need for:-

1. a study of the mixability of wheat flour with the flour of other food grains, especially sorghum, for the purpose of Sambusa-making with a view to converting this low grade food material into that of higher value.
2. ascertaining to what extent the nutritive value of a wheat-sorghum flour mix can be increased by stuffing

the Sambusa with pulses eg. soybeans without reducing its palatability.

3. a study of the latent scientific principles involved in Sambusa processing.

4. to evaluate the Sambusa by chemical analyses for overall energy value, protein and fat.

Indeed, the hope of stimulating interest in the underlying but underdeveloped science and technology of traditional food processes in East Africa, and the prospects of affecting nutritional enrichment programs in future work prompted the present studies on Sambusa. These were the primary objectives.

REVIEW OF LITERATURE

Sorghum and Soybean Production in Africa

Accurate statistics on world sorghum production are often lacking or incomplete; sometimes unspecified millet and sorghum grains are included in the same data. Crop estimates by FAO (17) indicate that total production of sorghum, millets and other major cereals has increased substantially from the 5-year average for 1948-52 to that of 1971. Sorghum world total production realized nearly a three-fold increase during this 23-year span.

A conservative estimate for world sorghum production in 1971 (the latest year for which production figures are complete) was projected as 49.0 million metric tons from nearly 39 million hectares. The United States was the largest producing country and region, with nearly 22.7 million tons or 46.3% of the world production on 7.6 million hectares or less than 20% of the total area sown to sorghum.

In Africa the leading producers are shown in Table 1. Egypt had the highest yield of 42,700 Kg of sorghum per hectare. In production, the three major regions shared almost equally:- the western Hemisphere, Asia and Africa produced respectively 38, 37 and 24% of the world's sorghum grain; Oceania (Australia mainly) and Europe together produced less than 1%.

For soybeans the production data are even less complete than those for sorghum. However, the FAO data (17) give a total production of 45,000 metric tons from 62,000 hectares with an average yield of 730 Kg per Hectare in Africa for 1971. The leading country was Nigeria with a productior of more than 75% of the total African crop of soybeans.

TABLE 1. SORGHUM GRAIN PRODUCTION AND PROPORTION OF THE TOTAL AFRICAN CROP IN 1971 FOR THE TEN LEADING COUNTRIES[a]

COUNTRY	AREA (1000 Hec)	YIELD (100 Kg/Hec)	PRODUCTION (1000 Metric) Tons	% OF AFRICAN CROP AREA	% OF AFRICAN CROP PRODUCTION
NIGERIA	4000	8.8	3500	33.5	36.4
SUDAN	1950	7.7	1500	16.3	15.6
ETHIOPIA[b]	2225	6.2	1375	18.6	14.3
EGYPT	210	42.7	897	1.8	9.3
UPPER VOLTA	1070	5.4	576	9.0	6.0
MALI[b]	650	6.9	450	5.4	4.7
CHAD[b]	525	6.8	358	4.4	3.7
UGANDA	275	12.1	332	2.3	3.5
SENEGAL	525	6.2	325	4.4	3.4
NIGER	500	6.0	300	4.2	3.1

Total area : 11,930

Total Production: 9,613

[a]Adapted from FAO Production Report, 1971.

[b]Calculated as one-half the total given for both sorghum and millets.

The Structure of the Mature Sorghum Kernel

The importance of structure of the sorghum kernel is related to various problems that must be considered when the grain is stored. The pericarp, for example, is known to have characteristics that allow water movement and mold invasion. Secondly, the relationship between structural parts is the basis for many types of milling processing. Thirdly, the structural parts differ in chemical composition. Thus, when they are separated in processing the products and by-products obtained differ characteristically in composition.

In general, the structure of the sorghum kernel is similar to that of the corn kernel. The differences between the two grains in kernel size and shape are obvious but structural parts lie in the same relationship to one another. There are a few minor differences in structure between the kernels of corn and sorghum:-

1. The mesocarp in sorghum contains small starch granules.
2. In sorghum, the nucellar layer may be wholly or partially resorbed by maturity. When present (wholly or in part), it is always pigmented.
3. The small starchy endosperm cells just beneath the aleurone layer are more abundant than in corn.
4. The germ is proportionately smaller in sorghum than in corn.

The typical sorghum kernel may be divided into the following parts (37):-

(i) Bran

(ii) Endosperm (including aleurone cell layer)

(iii) Embryo or Germ.

Sorghum Milling

For the use of sorghum as food in East Africa to be increased, varieties should be selected which display quality factors suited for their intended end use from among the seemingly limitless array of sorghums available. Therefore, varieties representing a cross section of the available array need to be evaluated for quality factors and the importance of these factors in the different processes that may be used to provide basic foods with popular appeal. It is recognized that other factors (i.e yield, agronomic characteristics, resistance to diseases and pests etc) in addition to those that will be dealt with here must be considered in the ultimate selection of any variety. Whereas it is recognized that certain sorghum varieties should be capable of local processing by the grower in remote areas, following more or less the traditional patterns, the large-scale development of this cereal will ultimately require commercially attractive varieties to be made available to the millers and processors in urban areas. With increasing urbanization in East Africa, commercial processing of sorghum must eventually follow the development pattern noted for maize (corn), wheat and more recently rice.

There are three general methods for removing the seed-coat from cereals:-

1. Roller-Reduction milling
2. Wet skinning
3. Dry Abrasion milling

Roller-Reduction milling: This system, universally used for the milling of wheat, can be applied to sorghum with varying degrees of success depending upon the nature of the bran and the endosperm of the grain.

Shepherd et. al (40) evaluated the roller milling characteristics of 15 sorghum varieties with the Buhler Experimental mill. The results on the fifteen samples are given in Table 2.

The column of crude protein content for the whole grain on an "as received" basis, indicates that sorghum can display a spread of protein levels almost comparable with that of wheat. The column on total flour yields gives a relatively low value range of 48 to 59% flour.

Hahn (21) concluded that roller milling of grain sorghum would be expensive, inadequate as to the flour yields, degree of refinement and purity of products because of the specky nature of grain sorghums.

Wet Skinning: Shepherd et. al (40) applied a wet skinning procedure described by Freeman and Watson (19). A 200g sample was stirred with 30 mls of 20% caustic soda solution and allowed to stand at room temperature for 15 minutes. Then 400 mls of water at 70°C was added, mixed and the mixture transferred to a Waring blender fitted with rubber covered paddles. Stirring at 3000 rpm for 5 minutes followed, and the skins and fines were floated off by upward current in a tall beaker. The grain was air-dried for 24 hours and weighed. Their grain yields ranged from 40 to 70%.

Though the outer bran can be removed by these procedures, the colored testa, when present, remains firmly attached to the endosperm. The germ was not removed, and a darkening of the area containing the germ was marked when alkali was used in the process.

Thus wet peeling systems have not yet been found effective in overcoming the milling problems of grains having dark testa.

TABLE 2. YIELDS FROM BUHLER MILL, SAMPLES TEMPERED TO 17% MOISTURE

Sample Number	Break Flour	Reduction Flour	Total Flour	Pollard	"Bran	Protein (Nx6.25) (Whole Grain)
	%	%	%	%	%	%
1	6.2	49.6	55.8	25.6	18.6	11.0
2	10.8	40.0	50.8	32.3	16.9	10.5
3	10.3	47.9	38.2	26.8	15.0	8.3
4	17.9	41.4	59.3	19.6	21.0	8.7
5	13.3	35.9	49.2	25.8	25.0	10.2
6	14.2	40.9	55.1	22.8	22.1	9.3
7	16.0	38.2	54.2	25.9	19.9	10.4
8	15.6	38.3	53.8	26.6	19.5	10.0
9	12.8	38.4	51.2	31.2	17.6	11.1
10	11.4	42.0	53.4	29.8	16.8	12.3
11	12.0	37.6	49.6	31.9	18.4	12.0
12	11.8	38.2	50.0	30.8	19.2	10.3
13	9.2	39.2	48.4	34.6	16.9	13.0
14	11.0	39.4	50.4	31.5	18.1	10.8
15	11.7	37.2	48.9	31.0	20.1	11.5

In addition, Freeman and Watson (19) noted reductions in starch yields caused by peeling. These tended to negate the advantages of the method and may have prevented acceptance of this process on a commercial basis.

Dry Abrasion milling: The barley pearler has proven satisfactory for pearling or decortication of cereal grains. There are two types, one which contains a cylindrical mill stone revolving inside a horizontal perforated cylinder and the second which consists of 6 to 8 abrasive discs coated with carborundum revolving rapidily within a vertical perforated cylinder. Hahn (21) reported the composition of pearled grain obtained with a barley pearler. As the amount of bran removed from the kernel increased, the protein, oil, fiber and ash content of the pearled grain decreased. The composition of the kernel remaining after removal of 39% of the kernel weight was close to that of pure endosperm obtained by hand separation.

The Chemical Composition of the Mature Sorghum Kernel

A comprehensive review of available literature on the chemical composition of the mature sorghum kernel was made by Wall and Ross (46) in 1970. This review indicates that the chemical composition of the mature sorghum kernel is only beginning to be known. However, it is desirable to re-evaluate these proximate analyses if new food products are to be developed.

Bredon (9), who analysed samples of sorghum from various parts of Uganda, found large variations in composition (Table 3).

TABLE 3. COMPOSITION OF SORGHUMS GROWN IN UGANDA

Sorghum Samples	No. of Samples	Protein	Fat	Carbohydrate	Fiber	Ash
		%	%	%	%	%
White seed	15	9.1-13.7	1.8-5.2	68.4-73.3	1.4-4.9	1.3-3.3
Red seed	5	8.0-10.9	2.1-3.3	69.4-74.5	1.8-2.8	1.8-2.7
Brown seed	11	8.1-11.7	2.0-4.0	70.0-74.2	1.7-4.1	2.2-4.5

The Protein of Sorghum

From the nutritional point of view, the variations of the greatest importance are those in protein: with a consumption of one pound per day the difference due to variations in protein content would be 18g, perhaps a quarter of a satisfactory protein intake for an adult man.

Four simple classes of proteins have been reported in the sorghum kernel (46), namely:- the glutelins, albumins, globulins and prolamines. These have been classified on the basis of their solubility; thus the albumins are soluble in water, the globulins in saline solutions, the prolamines in alcohol and the glutelins in alkaline solutions.

The most abundant fraction in sorghum protein is the prolamines. Johns and Brewster (25) extracted the fraction using 70% boiling ethanol and found it to be 67% of the crude protein. To avoid denaturation of the protein, Jones and Csonka (26) extracted it at 60°C. Virupaksha and Sastry (44) used boiling ethanol (60%) and found the fraction ranged from 30 to 60% of the total crude protein in 6 varieties of sorghum. Like zein from corn, the prolamine fraction is poor in nutritional quality.

As seen from Table 4, from data by Virupaksha and Sastry (44), prolamine is lacking in some essential amino acids like lysine, and methionine. Glutamic acid content is high, but probably occurs as its amide glutamine, as indicated by the presence of large amounts of ammonia in acid hydrolysates. The solubility of the prolamine fraction in organic solvents is probably related to the presence of large quantities of neutral (non-polar) amino acids like leucine, and alanine.

Glutelin: Glutelin is the second major protein fraction. Virupaksha and Sastry (44) extracted this fraction using 0.4% sodium hydroxide for 2 hours at room temperature. The sample had previously been treated to remove saline and alcohol-soluble fractions. The insolubility of the glutelin fractions in neutral solvents has been attributed to their high molecular weights caused by disulfide bonds in the sulfur-containing amino acid like cystine. These bonds are, however, broken by dilute alkalis. Virupaksha and Sastry reported a higher content of lysine, histidine, arginine and glycine in glutelin than in prolamin, Table 4.

Albumins and Globulins: These fractions, although present in the smallest quantities, contain enzymes and other biologically active proteins. Jones and Csonka (26), using defatted meals of three sorghum varieties, extracted only 12.7 to 13% of the total nitrogen in 10% sodium chloride solution. Virupaksha and Sastry (44) extracted 2 to 8% of the protein with water from endosperm meals of several sorghum varieties. An additional 2 to 10% was extracted with salt solution.

TABLE 4. AMINO ACID COMPOSITION OF PROTEIN OF A SORGHUM GRAIN (CSH-1 BIJAPUR)

(Percent of Protein)

Amino acid	Endosperm Meal	Protein Fraction: Globulin	Prolamine (Kafirin)	Glutelin
Lysine	1.7	3.36	0.14	3.12
Histidine	2.16	1.45	0.67	3.12
Arginine	3.25	6.14	0.66	5.91
Aspartic acid	6.25	8.68	6.72	9.07
Threonine	3.81	4.87	-	4.88
Serine	4.5	5.55	3.32	5.38
Glutamic acid	29.75	15.8	25.07	24.08
Proline	10.31	5.33	11.63	14.86
Glycine	3.27	6.25	1.28	5.33
Alanine	12.58	6.74	13.96	9.4
Half cystine	1.08	1.99	Trace	1.21
Valine	7.25	6.46	5.88	5.5
Methionine	1.51	2.24	1.33	-
Isoleucine	4.91	3.45	5.04	4.07
Leucine	16.58	6.72	15.33	12.49
Tyrosine	4.64	4.01	5.17	3.23
Phenylalanine	6.4	4.77	5.84	4.9

Amino acid composition of the globulin, prolamine and glutelin fractions of sorghum endosperm proteins as determined by Virupaksha and Sastry is given in Table 4. Since lysine, threonine and methionine are the most deficient amino acids in cereals, it is evident from Table 4 that the albumin and globulin proteins are the best in nutritional value; prolamine is the poorest, and glutelin is intermediate. The large amount of prolamine is responsible for the low nutritional value of sorghum grain protein.

In general, the sorghum proteins are not as high in biological value as those of many legumes. Prolamine will not maintain life in the rat, but when supplemented with limiting amino acids and fed at a sufficiently high levels, it maintains nitrogen balance in the rat and serves as the source of protein in the diet.

Sorghum Lipids

The lipids in sorghum are important in human nutrition, but they may also contribute to the development of off-flavors and rancidity in sorghum-based food products, like the Sambusa. The extent of unsaturation affects the nutritional value and the storage stability of the Sambusa.

The chemical composition of sorghum lipids has been investigated by a number of workers (4, 13, 45). The lipids are largely located in the germ and bran. The average oil content of the whole grain is 3.6% with contents of the endosperm, germ and bran, 0.6, 28.1 and 4.9% respectively.

With fractional distillation and spectroscopic techniques, Baldwin and Sniegowski (4) studied the fatty acid composition of lipids associated with four main fractions from wet milling of commercial hybrid sorghum. The fractions included germ (52% fat), starch (1% fat), gluten (7% fat) and fiber (3% fat). Although gluten and germ fats had similar amounts of oleic and linoleic acids, more polyunsaturated fatty acids were found in the gluten lipids. Both unsaponifiables (10%) and free fatty acids (20%) were found in each of gluten and fiber lipids.

Dalton and Mitchel (13) studied the composition of sorghum grain wax by fractionating it on columns of tricalcium phosphate and silicic acid. Of the materials eluted from the columns, approximately 5% was paraffins, 49% esters of long chain fatty alcohols, and 46% free alcohols. Each of these fractions was shown to be a mixture of related substances rather than a single compound as indicated by melting points, x-ray diffraction studies and infrared spectra. Chain lengths of the individual hydrocarbons, alcohols and fatty acids were mostly 26, 28 and 30 carbons.

Wall (45) examined the nonpolar lipids from ground whole sorghum grain of three varieties by thin-layer chromatography. He found that the largest single fraction was composed of triglycerides. Also present were small amounts of hydrocarbons, sterol ester, fatty acids, monoglycerides, sterols and phospholipids. The triglyceride components were further separated by gas-liquid chromatography. This revealed similar triglyceride composition amongst the 3 sorghum varieties as follows: C_{50}, 3%; C_{52}, 32%; C_{54}, 64% and C_{56}, 1%.

For the bound lipid fraction, extracted from sorghum grain with methanol-chloroform mixture, the major components were reported as phospholipids. These substances represented 5% of the total lipids.

Wall (45) reported that the phospholipid could be fractioned into a 95% ethanol-soluble lecithin fraction; the remainder constituted the cephalin fraction. Compounds resembling lecithin were revealed by thin-layer chromatography as phosphatidylethanolamine and phosphatidylserine. An inositol compound was also detected on the chromatogram. This compound contained phosphorus, glycerol, inositol and fatty acids in the ratio 1: 1: 1: 2.

Phenolics

Certain grain sorghum varieties have objectionable characteristics in relation to the palatability of food products for human consumption. Research (14, 36) has revealed that tannins cause bitterness, an unpalatable color, lowered digestibility, and poor acceptance of products made from sorghum. Tannins are found in the pericarp or bran of the grain and can be removed by peeling. An additional handicap is the deep pigmentation of the seed coat of certain sorghum varieties. Red pigments often change to an undesirable blue-gray charcoal or muddy color in baked foods, depending on pH. Psychologically, food of such color is considered inedible. Grittiness, originating from the corneous endosperm portion of the grain, is present in sorghum flour, even when milled to the "fine meal stage" and is unacceptable to many (8). Fractions of the grains have yielded more desirable products. The germ meal layer has a pleasant nutty flavor, and the floury endosperm lacks the grittiness of the whole grain.

Pigments: Pigments in several red varieties of sorghum were investigated by Nip and Burns (32). Orange pigmentation was found in epicarp, in cross-cell and tube cell layers of the pericarp, and in seed tip portions of the grain. Anthocyanin and flavone compounds were tentatively identified by chromatographic separation and characterization, spectrophometric measurements, color reactions, and hydrolysis of products.

Wall (45) reports the extraction, with methanol, of red-brown pigments from a sweet sorghum and their separation on calcium carbonate columns. Isolated were two anthocyanidins, blood red sanguisorghuidine and ruby red rubisorghuidine. The pigments were pH sensitive and soluble in alcohols and acetone, but were insoluble in water.

Blessin (7) was able to detect anthocyanogens in yellow and red sorghums but not in white endosperm varieties. When present, these compounds were located mainly in the pericarp and were generally absent from the endosperm. The anthocyanogens in aqueous extracts of the whole grain were purified on ion-exchange resins and separated by paper chromatography. He treated the anthocyanogens with concentrated hydrochloric acid, and based on spectral absorption, fisentinidin was tentatively identified as one of the reactions products resulting from the acid treatment. Further investigation indicated the presence of three anthocyanogen-like flavonoids-chromagens 1, 11, 111 in methanol extracts of sorghum pericarp (47). The compounds are polymerized substances similar to those reported in lignin. Upon hydrolysis the three chromagens yielded a flavanone, probably eridictyol, and an anthocyanidin, pelargonidin.

<u>Tannins</u>: Characteristically high tannin contents are associated with sorghum varieties with brown seed color. Sorghum diets containing high tannin levels retarded growth in poultry fed similar levels of tannic acid (12). Following water extractions, the tannic acid levels were determined colorimetrically with Folin-Denis reagent. Tannin contents in the brown-seeded sorghums ranged from 1.3 to 2% compared to a range of 0.2 to 0.4% in other common varieties.

Despite such objectionable characteristics associated with the presence of phenolics in sorghums, researchers have developed acceptable food products from sorghum. As early as 1942, Bavousette and Klepp (5) found that sorghum flour could be substituted for one half to two-thirds of wheat flour in quick breads and yeast breads. Boren developed (8) additional formulas for these products, plus a multi-purpose mix in which sorghum flour was substituted for 50 to 100 per cent of the wheat flour. Miller, studying the acceptability of a sorghum bread with properties similar to those of corn bread, found (29) that varieties with the highest percentage of amylopectin were preferred for sorghum bread. A "Freedom Meal", developed by the Nebraska Department of Agriculture to utilise Nebraskan crops, included 26 percent grain sorghum, 26 percent wheat, 26 percent corn, and 15 percent soy; when fortified with dried milk, it provided a protein-rich food for babies, the infirm, the elderly or for persons suffering from malnutrition (41).

Starch in Sorghum Grain

The cereals are predominantly carbohydrate foods. The principal polysaccharide present in the sorghum kernel is starch. After enzyme and acid hydrolysis, starch content of defatted sorghum grain meals may be determined as reducing sugar. Starch is also known to rotate polarized light and its content may be determined by solubilizing the starch and measuring the light rotation. Patel et al. (33) reported the specific rotation $[\alpha]$ D, of sorghum starch to be 203.1 to 203.5 compared to wheat starch which was 202.7 to 203.2. By these procedures it was found that starch constituted 68 to 73% of the grain from 20 varieties of sorghum. Hübbard (24) reports that starch comprises 83% of the endosperm, 13.4% of germ and 34.6% of bran obtained by hand dissection of the sorghum grain.

Sorghum starch occurs in granules generally comprised of a mixture of two types of molecules, both of which are polymers of glucose. One kind of starch, amylose, a polymer of glucose units is joined exclusively by α-1, 4 linkages to give a linear chain. Amylose dissolves with difficulty in water, from which it can be precipitated with butanol; and is known to complex with iodine to yield a blue color. The other type, amylopectin, has been shown on the basis of methylation studies to be a branched-chain polysaccharide. This fraction is more readily soluble in water or an aqueous butanol solution and gives a red color with iodine. Foster (18) found the amylose molecular weight ranged from 2 to 7 x 10^5 while amylopectin molecules had a higher value of 1 to 10 x 10^6.

Amylose may be determined in starch solutions either by amperometric titration with iodine or by photometric estimation of the blue color formed with iodine. Wall et al. (46) reported that in normal varieties of grain sorghum, amylose content of starch ranged from 23 to 28%; amylopectin comprised the remaining starch. No sorghum was found to be high-amylose above 28%, in contrast to corn where high-amylose strains have been developed. Starch in waxy sorghum varieties is essentially all amylopectin.

Vitamins and Minerals in Sorghum Grain

Well established is the importance of vitamins and minerals in grain to animal and human nutrition. Ash is the mineral residue left when a sample of ground sorghum kernel is heated in a silica dish under prescribed conditions until all organic material is destroyed, but without causing the volatilization of the non-combustible constituents. In the ash of sorghum, phosphorus, magnesium, chlorine and calcium predominate, followed by iron, manganese and copper. A considerable part of the phosphorus (40 to 75%) is in the form of phytin, the calcium or magnesium salt of phytic acid (6) and there is considerable interest as to the availability of phosphorus in this form.

For sorghum grain vitamin composition, Hubbard (24) reported that the grain contains approximately the same quantities, as corn, of riboflavin, and pyridoxine; but has more pantothenic acid, nicotinic acid and biotin. Grain sorghum compares favorably with wheat and rice with regard to levels of thiamine and niacin.

Cereal Food used in Uganda (East Africa)

When sorghum is required for eating the heads are removed from the store and threshed and the grain is tossed in baskets to remove pieces of stalk and other debris. Before stone grinding, the grain is lightly heated in a dry metal pan and roughly winnowed to remove some of the outer skin. To cook the ground meal, it is first sprinkled on water that has been heated almost to boiling. For taste, the water may contain sour milk, or juice from boiled immature mangoes and lemons. Water is then allowed to boil and more flour is added and stirred until a thick paste is obtained. The paste is ready to eat after it has been cooking for about 15 minutes. A thin porridge, most often given to children, is made by using a smaller proportion of flour to water.

Food preparations are generally simple. In Karamoja in Uganda the cooked grain may be mixed with blood from cattle. The method used to prepare flour depends on the grain flouriness or corneousness. The soft floury varieties are often stone ground. The flours from such sorghums are most often mixed with cassava, or sweet potato flours which form about $\frac{1}{4}$ of the mixture. The use of the mixture gives foods of better elasticity. Flour from finger millets may also be used in the mixture. The hard, corneous types are treated differently; these are pounded skilfully in a mortar and pestle to remove the pericarp. Pericarp removal is often simplified by presoaking the grain in water for some time. The endosperm is then ground into excellent flour. A common practice is that used for high altitude sorghums of western Uganda. These are of the soft, brown grain type, and the grain is malted by being soaked in water, mixed with ash and germinated. The grain is then pounded to remove the bran and dried. The soaking removes pigment and some of the bitter principle from the grain, and germination results in the production of sugars so that a sweet porridge can be made. The malted grain keeps very well which is a great advantage in a country where storage pests are a major problem.

The taste for foods is much influenced by upbringing. Jowett (27), using rank correlation methods, showed that the Iteso people of eastern

Uganda much preferred sorghum mixed with finger millet. Inquiries showed that the food mixtures were in fact widely used.

Food Legumes: Status and Potential

In the developed countries, legumes are almost an insignificant part of the diet and there are no nutritional reasons for reversing the downward trend. However, in developing countries, which are short of protein, the situation is different. In countries where starchy materials such as cassava, yams, sweet potatoes and bananas replace cereals as staple foods, legumes assume much greater importance in providing needed protein.

Schaik (38) gives the following advantages of food legumes:-

1. Commonly grown, worldwide.
2. High in total protein, 18-25 percent.
3. Good essential amino acid balance. Though limited in sulfur containing amino acids, methionine and cystine, legumes are high in lysine thus making them particularly valuable as supplements to cereal diets.
4. Commonly consumed at all economic levels and consequently no problems of acceptance of new foods.

Soybean and soybean products have been widely used in fortification as well as in new food development programs. Thus foods have been produced from soy grits and flours by extrusion at high temperature to form textured masses which can be rehydrated into meat-like pieces (34).

At the lowest level of sophistication are the defatted "toasted" soy grits and flours. These have been gaining food outlets in a variety of products, the most noteworthy development being the US relief food mixture CSM (for corn/soy/milk). Full-fat soy flours, containing approximately 40% protein and 20% fat, have had modest use for many years in infant formulas and baked goods. On the other hand, a modern counterpart of tofu (soybean curd), namely, soy protein isolate, first used commercially in the US as paper coating and glue, has become increasingly important as a starting material for a variety of sophisticated foods including the meat analogs produced from spun soy filaments (34). At an intermediate level of sophistication and cost, soybeans have been used in the production of many varieties of foods, including beverages (31).

MATERIALS AND METHODS

Experiment 1: Dry Abrasion Milling of Sorghum

A sorghum variety G766W was obtained and stoned-milled to obtain flour of similar granulation to that used in peasant homes in East Africa.

Cleaning of Sorghum:

The sorghum variety under study was fumigated and then passed through a Forster Scourer to remove dust and adhering glumes. The sample was then further cleaned on a Hart-Carter Dockage Tester using the riddle, screens, feedrate and air setting on the aspirator recommended by the manufacturer for cleaning.

The cleaned sample was then sized, Fig. 2, on 7W so as to separate the larger kernels from the smaller kernels. Such a separation facilitates a uniform polishing action for grains of similar size. A Satake Grain

Testing mill was used to debran the grains. Such equipment is often set to skin the grain by variations in:-

1. the feed gate opening
2. the discharge gate opening
3. the clearance between the abrasive surfaces
4. the time the grain remains between the abrasive surfaces.

The only variable parameter used in these studies was the duration of the polishing action: 45, 90 and 120 seconds. The two fractions obtained from sizing, were then polished separately but later combined to be sifted on 8W, 14W and 20W. The fraction on 14W contained germ and some bran; this was aspirated on a Dakota Seed Blower. The heavy fraction was combined with the fraction on 8W and ground through the Brabender Rapid Test Mill (stones) whilst the light fraction was further separated by appropriate air pressure into germ and bran. The fraction on 20W contained some germ whilst the throughs were entirely bran.

Sifting of the ground sample was done on 20W and 40SS. Trace amounts of the ground sample remained on 20W whilst the overs and throughs of 40SS were combined and designated as sorghum flour.

Various substitutions of sorghum flour were made into 1000 gms of US Government All Purpose Flour. Each of these was put into a bowl of a Hobart N-50 mixer, fitted with a B-flat paddle. The mixture was then blended at a low speed of 575 rpm for 30 minutes to obtain a uniform distribution of wheat and sorghum flours. Occasionally, the flours were scraped off the sides of the bowl and paddle into the center of the bowl. In all, blends containing 5, 10, 15 and 20% sorghum flour were made.

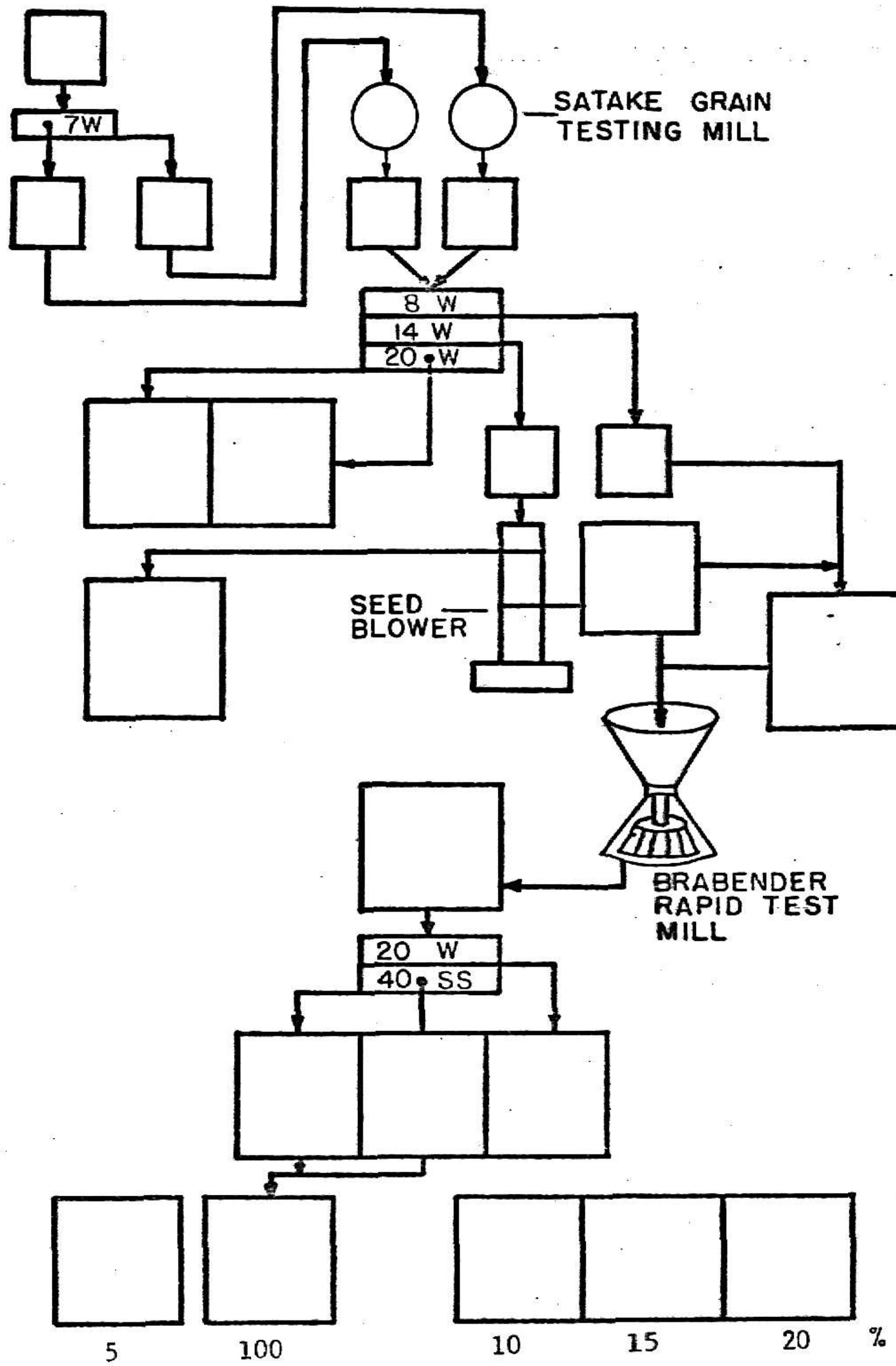
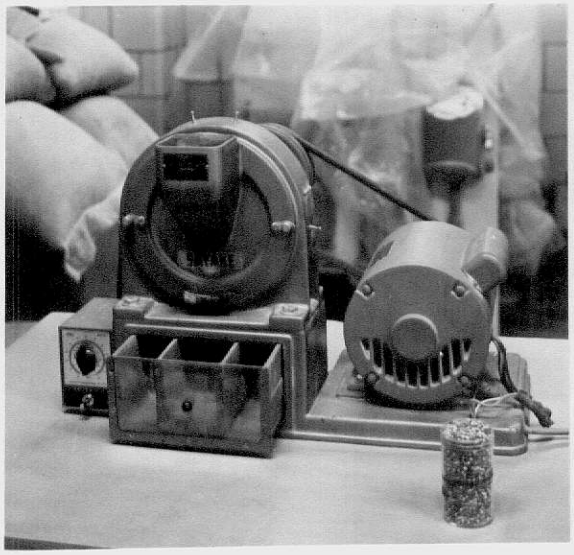
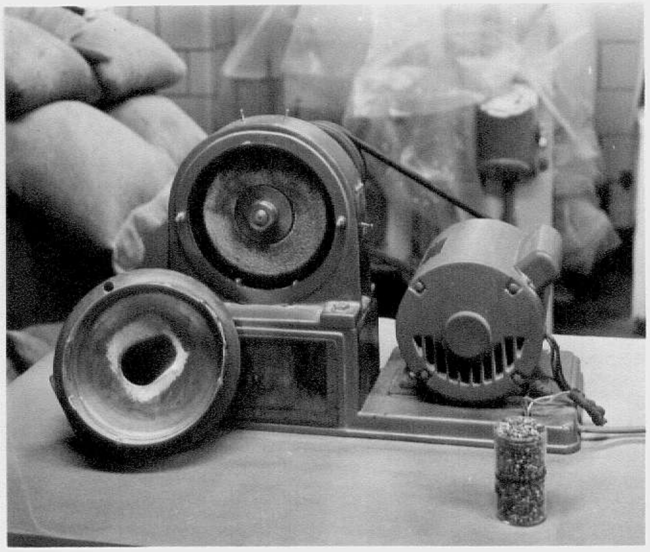


Figure 2. A Schematic flow for the dry milling of sorghum for Sambusa

PLATE 1

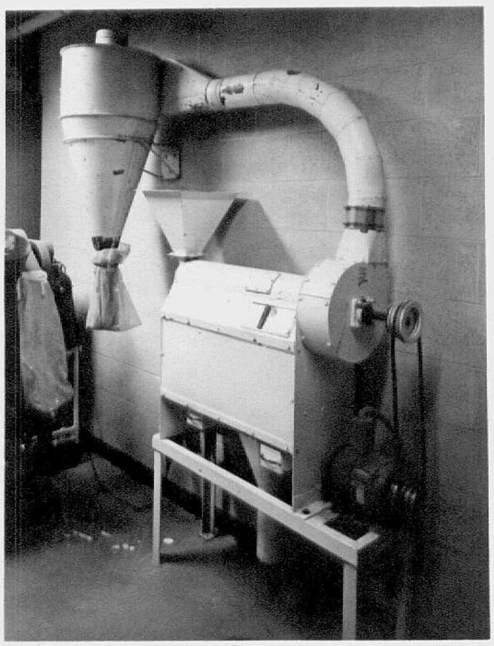


A



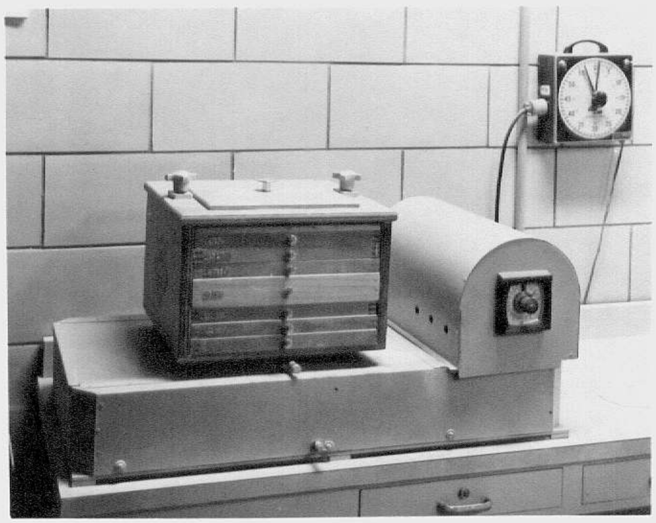
B

A Satake Mill Showing the Stone in B



C

A Forster Scourer



D

A sifter

Experiment 2: Standardization of Processing conditions and Dough Handling and Processing

After a series of trials a simple formula, Table 5, for the making of the Sambusa was developed on the basis of the existing traditional methods. The basic ingredients were wheat-sorghum flour mix, water and whole soybeans. However, for the chemical and organoleptic analyses to be comparable during the studies it was important to minimize the inherent variations in the values that could be caused by variations in processing methodology. Towards this end the following conditions were standardized. Only one type of US Government All Purpose flour, from one source and received in one batch, was used. Only one variety of sorghum (G 766W) was milled and the flour was blended with wheat flour, in various proportions. The selection of all purpose flour was based on the fact that it is the flour type often imported or donated and used in East Africa for Sambusa making. Moreover, the protein content on dry basis of the wheat flour (11.5%) and whole sorghum (10.8%) is comparable to that of East African sorghum. To minimize variations in dough thickness, a rolling board with raised "shoulders" of a known thickness ($\frac{1''}{32}$) was used to flatten the dough on. The dough was divided into balls weighing 30 gm each.

The amounts of ingredients used, expressed in grams and in percentage based on the weight of the wheat-sorghum mix, were as shown in Table 5.

TABLE 5. DEVELOPMENT OF A STANDARD FORMULA

Ingredient	%	Amount (gms)	Cals.	Prot. (gm)	Fat (gm)	CHO (gm)
Flour	100	100	345.8	10	0.2	76
Soybeans	100	100	432.8	35.7	17.6	32.9
Cooking oil (Grain)	2	2	18.0	-	-	-
Water	45	45	-	-	-	-
Salt	1	1	-	-	-	-
Onions (Raw)	5.0	5.0	-	-	-	-
Curry Powder	.2	.2	-	-	-	-
Pepper	.2	.2	-	-	-	-
TOTALS	253.4	253.4	796.6	45.7	17.8	108.9

Cooking Yield: 4 Sambusas per 100 gm of dough

For ease and convenience of description, the procedure was in three stages and reference is made to Fig. 1, pages 5 and 6.

Stage 1: Preparation of the dough

The control product (A) was made by weighing 100 gm of all purpose flour and 1 gm of salt into the mixing bowl of a micro-mixer fitted with a timer. A depression was made into the center of the heap thus formed and 45 mls of distilled water was dispensed into it, then it was mixed for 5 minutes. The stiff but plastic dough formed was transferred to the rolling board. It was then covered with a damp cloth to minimize drying of the dough.

Stage 2: Shaping and Stuffing

Doughs were divided into 30 gm pieces. Each piece was separately rolled out and flattened on the special rolling board to obtain a dough of $\frac{1''}{32}$ thickness. A triangular cookie type cutter, with 7" long sides, was firmly applied on the flattened dough to cut the desired shape. Another equilateral triangle of 3½" sides was marked on the dough and a weighed amount of stuffing (25 gm) was centrally positioned into the marked area. The remaining portions of the triangle dough were folded so as to enclose the stuffing and the joints were firmly pressed to prevent the stuffing from rolling out. The weight of this formed raw Sambusa was taken.

Stage 3: Deep fat frying

Eight raw Sambusas from the control wheat flour were made for frying in one batch. Crisco fat was used, preheated to 375°F in a Sunbeam Cooker-Fryer. Cooking in oil lasted 5 minutes. The cooked Sambusa was allowed to cool and the final weight of each identified Sambusa was taken.

PLATE 2

Rolling Equipment (left) and Cooker-Fryer (right)

Energy Value: The method of Atwater and Snell (3) was employed to determine energy levels. This consisted of multiplying the values obtained from chemical analyses for protein, fat and carbohydrate by factors of 4 9 and 4 calories per gram, respectively.

Using this procedure, replicate experiments were designed to study the effect of limiting and excess water levels and of various mixing times on the quality of the Sambusa.

Experiment 3: Preparation of the other Sambusas

Variables from the control Sambusa were made using flours that were made by subtituting 5, 10, 15, 20...% of the wheat flour with sorghum flour and these will now be referred to as flours B, C, D, E... respectively. By trial various water volumes that gave a dough of the right consistency were found. Using the procedure outlined above, the various Sambusas were made. However, for organoleptic evaluation the Sambusas were allowed to cool to 80°F.

Experiment 4: Evaluation of the Sambusas

The following objective and subjective measurements were made to evaluate the Sambusa.

(a) Objective measurements:

1. Cooking loss: As mentioned above the Sambusas were weighed before and after frying.
2. Fat Absorption: By petroleum ether extraction, the fat absorption of various Sambusa types were determined before and after frying, based on a starting weight of 100 gm of raw Sambusas.

3. Color: Reflectance (Rd) A Gardner Automatic Color Difference Meter, Model AC-2A series 200, was used for color determination. A standardized tile which was as similar in color to the Sambusa as possible (Rd = 15.53, a = +9.33, b = +13.10) was used to standardize the instrument. Rd (reflectance) values were determined on duplicate samples cut from the center of unfolded but fried dough of the Sambusa to fit the color cell. Three readings were taken on each sample; between readings the sample was turned through a 120° angle. The color value of each sample was considered to be the average of these three readings.

4. pH: The pH of the dough was determined on a Beckman Model 76 Expanded Scale pH meter. A buffer with a pH of 6.86 was used to standardize the instrument. The dough was soaked in 100 mls of distilled water for at least 45 minutes. The dough and water were placed in a Waring blender and blended for one minute. The slurry was transferred to a 150 ml beaker and the pH reading taken at $26^{\circ}C$.

(b) Subjective Measurements

Scoring System: To evaluate the laboratory performance of the wheat-sorghum flour blends for Sambusa preparation, useful criteria were needed and therefore the opinion of some consumers was sought. The term performance is used here to indicate an assessment of those properties that might affect product acceptability.

Thirteen East African students (5 Kenyans, 5 Ugandans and 3 Tanzanians) currently studying in the United States were asked, independently, to describe the factors they considered important with respect to the eating qualities of the Sambusa. As a result of these interviews and correspondence a score card system was developed to define some of the important characteristics of the organoleptic properties of the Sambusa. These parameters of quality were then assigned quantitative values. This score system is shown in Table 6, and was used throughout the studies. The method recognizes three major characteristics of the Sambusa, viz:-

(i) general appearance in relation to color , shape and size.

(ii) texture and other internal features like grain.

(iii) flavor and aroma characteristics including taste and odor.

The higher the score the more desirable the factor evaluated in the final product. A seven-point scale was used, and thus for a very desirable and excellent quality a full value of 7 out of 7 was awarded; 6 for desirable, 5 for moderately desirable, 4 for neutral, 3 for slightly undesirable, 2 for undesirable and 1 for very undesirable.

To be rated as very desirable and excellent it would be implied that no improvement was needed. By desirable, the product must be enjoyed in eating and arouse the desire for minor improvement only. Moderately desirable means the product could be eaten without enthusiasm and that some improvement was required. If the product was slightly edible it was rated as slightly undesirable; if barely edible, it was rated as undesirable; and if inedible, it was rated as very undesirable.

Limitations of the scoring systems are readily recognized because of the small population sampled. In that some persons examining the products in the laboratory were not native consumers, only petential acceptability

TABLE 6. SCORE CARD FOR THE SAMBUSAS

Name ______________________ Date ______________________

Factor (characteristic)	Sample				Comments
	1	2	3	4	
1. APPEARANCE: Triangular shape, well cooked					
2. COLOR: mottled yellowish to brown crust					
3. TEXTURE: crust - crisp stuffing - chewy					
4. FLAVOR: pleasing, characteristic - not raw tasting					

Scoring Key
7 Very desirable
6 Desirable
5 Moderately desirable
4 Neutral
3 Slightly undesirable
2 Undesirable
1 Very undesirable

of the flour blends could be predicted. Determining consumer acceptability of the products would require in situ testing. It will be realized, nevertheless, that if the system is improved it will have promising applications because it can be used by persons unfamiliar with the Sambusa since it offers detailed descriptions as to how the scores are made.

How the Products were scored

1. Appearance:

    (a) Shape:- proportionate dimensions. This is expected to be an equilateral triangle (having all faces and sides equal). The food stuffing is expected to fill up the maximum space. For this experiment a perfectly equilateral triangle of Sambusa with a full body would be rated as very desirable, score,..7.

    (b) Size:- the size and the type of stuffing of the Sambusa is generally related to its price. Prices range from 20 to 80 East African cents (3 to 35 American cents). The size and shape characteristics would be considered under general appearance.

2. Color: should be normal for the Sambusa and pleasing to the eye; Uniform and pale yellow to golden brown, with few dark spots..7.

3. Texture: this depends on the crust graininess and is determined by both touch and mouth feel. The grain here is defined as the degree of a sandy mouth-feel structure formed by the particle sizes of the sorghum flour in the crust of the Sambusa. Dry, smooth and crisp crust...7.

4. Flavor: this is detected by senses of taste and smell. A typical Sambusa odor with a well balanced taste would be rated as 7.

Experiment 5: Chemical Analyses

Analytical experiments were designed to study the influence of dry milling on the proximate composition and amino acid content of the sorghum flour used to produce Sambusa. Data obtained were reported on dry basis.

Moisture Content

Moisture content was determined by drying the samples for one hour at 130°C by the AOAC (2) method 14.004 as follows. Exactly 2 gm of sample were placed in a cool, weighed aluminium dish, provided with a cover, and the cover dried separately for one hour at 130°C. Then the dish was covered while still in the oven, transferred to a dessicator, allowed to reach room temperature and weighed. The loss in weight represented the moisture content of the sample.

Ash Determination

Ash was determined by incinerating weighed and powdered sample for 24 hours at 550°C according to the AOAC (2) direct method 14.006. Exactly 4 gms of the sample was weighed into a silica crucible that had been ignited, cooled in a dessicator and weighed. The sample was then ignited in a muffle furnace at 550°C for 24 hours, then the ash was cooled in a dessicator and weighed.

Crude Fat

The crude fat or ether extract determination was based on the procedure described by AOAC (2) Method 7.048. Two grams of the sample was wrapped in Whatman No. 4 filter paper, placed in a thimble and extracted with petroleum ether (50 mls).

The extracted sample was dried for 30 minutes at 100°C, cooled in a dessicator and weighed. The difference in weight was recorded as crude fat.

Total Crude Protein

The protein content was estimated by the improved Kjeldahl method for nitrate-free samples approved by the AACC (1), Method 46-11. The Kjeldahl method was carried out in two steps; first the sample was digested with concentrated sulfuric acid and other reagents at elevated temperatures in order to convert all the nitrogen in the sample into ammonium sulfate. In the second stage, the ammonium sulfate thus formed was treated with a saturated alkali solution to liberate ammonia which was trapped into a standard solution, 0.125N sulfuric acid. Following the AACC procedure, a one gram sample was placed into Kjeldahl digestion flask. Appropriate amount of the digestion catalyst, consisting of powdered copper and potassium sulfates, was used together with concentrated sulfuric acid. The flask was placed on a digestion rack, heated gently until frothing ceased, and boiled briskly until frothing ceased and solution became clear (1½ hrs). The digested material was then cooled and diluted with distilled water. A saturated solution of sodium hydroxide was then added and the contents immediately distilled with the tip of the condenser immersed in the receiver containing standard sulfuric acid solution, 0.1253N; titrated with standard alkali solution, 0.1253N sodium hydroxide, using methyl red as indicator. Corrections were made for blank determinations on the reagents alone. Volume of sodium hydroxide was read directly from the buret (20 ml at top to 0 ml at bottom) and reported as % protein.

This result gave the protein (N x 5.7) and to convert to N x 6.25, the former was multiplied by 1.1 factor.

Carbohydrate

The carbohydrate content of samples was determined by the difference between 100 and the sum of the percentage values for moisture, ash, protein and fat.

Experiment 6: Amino Acid Analyses

Amino acid compositions of the protein in the whole sorghum variety G766W, polished sorghum G766W, its defatted germ, and defatted soybean sample were determined as outlined below. Representative samples of each of the above were chosen for the analyses. All extraneous and foreign material was removed by hand from all samples previous to any analyses. The cleaned samples were then ground and defatted where applicable. Kjeldahl nitrogens were run.

The flours were thoroughly mixed and repeatedly quartered to obtain representative sub-samples. Single samples of each were then weighed out to contain 10 mg $\pm$ 0.5 mg of protein. These were hydrolysed with 6N hydrochloric acid in sealed evacuated test tubes at 100 $\pm$ 1^{o}C for 24 hours. The test tube contents were filtered, and the filtrate evaporated to dryness. Excess hydrochloric acid was removed by repeated dilution with deionised water and evaporation to dryness. The hydrochloric acid free residues were made up to 10.0 mls with 0.20 M sodium citrate buffer, pH 2.2

Aliquots of the hydrolysates were taken, and amino acid analyses were carried out by ion exchange chromatography on a Beckman Model 120B amino acid analyser, according to the procedure of Moore et al. (30) and Spackman et al. (42). Results were calculated and expressed as grams of amino acid per 16 grams nitrogen, dry basis. Cystine, methionine and tryptophan were not reported because they are lost when hydrolysis is carried out using acids.

RESULTS AND DISCUSSION

Milling Experiments

The relative proportions of the "total edible" and non-edible fractions produced by milling sorghum (variety G766W) are shown in *Table 7*. Milling losses included moisture loss, dust and other material losses during grinding, sifting and weighing steps. It would be observed that percent total edible fraction, which was ground up into flour for Sambusa making, decreased from 90.8 to 76.7 as the duration of the polishing action increased from 45 to 120 seconds. This decrease was accompanied by an increase in the proportion of through 20W, discarded as "bran". With increasing time, there was a corresponding decrease of the fraction on 8W and an increase on 14W (brokens). Visual examination of the total edible fraction revealed that even with the most severe polishing, no satisfactory product could be obtained from this particular variety of sorghum. The best looking fraction amongst our samples had brown patched grains which when ground up, resulted in a light brown flour.

Good germ separation was realised when grain was abraded for 90 seconds.

In general, our total edible portions are much higher (77 to 81%) than those obtainable from either roller milling or wet skinning. At the village level, particularly in developing countries, this system of polishing lends itself to a simple 1-pass procedure which is cheap and efficient. It is clear that, in this system, as much of the grain surface as desired can be abraded; but commercial, nutritional and practical

TABLE 7. % YIELDS[a] OF PRODUCTS ON THE SATAKE GRAIN TESTING MILL

Duration of the Polishing Action (sec)	% Whole on 8W	% Thru 8W and on 14W, After Aspiration (Heavy)	% Total Edible, on 8W and 14W	% Thru 8W and on 14W, After Aspiration (Light) (Germ)	% Thru 14W and on 20W	% Thru 20W	% Recovery on 20, 14W & Fines	Comments on Appearance of whole kernel
45	85.7	5.1	90.8	1.4	0.7	6.5	99.4	Slightly polished, but redish brown pigment remained
90	68.4	10.3	78.7	3.0	1.0	14.9	97.6	Nearly completely polished,red pigment on outside of grains
120	42.9	33.8	76.7	1.6	3.4	17.0	98.7	Nearly completely polished product of mixed yellow and red spots

[a]Yields expressed on "as is" basis; and based on the weight of the original non-polished grain

considerations would set limits on the extraction, and suitable grain would be properly milled when not more 20-25% of its weight has been removed as "bran".

In general terms, what has emerged is that we can produce the following products, with an indication of the possible uses:-

Whole skinned kernels, (+8W, 14W; 45-120 sec.) - these can be parboiled like rice or bulgur (wheat).

Coarse Gits - coarse grits can be used in the preparation of porridge or similar end products.

Fine Grits, (+20W; 120-160 sec.) - may be used for extrusion products.

Flours - flours, in addition to being substituted for wheat flour used for Sambusa making, may be baked into biscuits, and scones. The by-products of any form of milling, generally bran and germ, will find a ready outlet in the animal feedstuffs along with similar by-products from corn milling. In addition germ might be defatted and used as part of the stuffing for the Sambusa.

Commercial Milling for Sambusa Flour Blends

Sorghum is an important cereal in East Africa. The grain is used for human food and for brewing. A suggested flow diagram for simple commercial milling to obtain wheat-sorghum blends for the purpose of Sambusa making appears in Appendix, Fig. 4.

Grain Sorghum from peasants' farms: The grain is normally harvested by hand. The usual storage bin is a woven basket smeared with a mixture of cow-dung and mud, standing on a small platform clear of the ground and covered with a thatched lid.

This unprocessed grain is subject to severe losses from insect damage. In addition, in the more humid regions of East Africa where the harvest is more difficult to dry thoroughly, the grain is stored on the head. Sorghum may also be stored temporarily in the field in large stacks of heads, built-up on a platform of straw. When thoroughly dry, the heads are then taken to be thrashed, being beaten with long sticks on a mud and cow-dung floor. These are the storage conditions of the grain that reaches the mill.

Cleaning and conditioning: With the grain from the storage conditions described above, it would be necessary to clean the grain as soon as received; the light material being blown off and the heavy material sifted. Iron or steel particles can be removed with electromagnets, (Fig. 4), or magnetic separators. The iron particles would be magnetised on reaching the separator and are held firm. If the grain is to be kept for any length of time before processing, it might be dried to 12 to 13 percent moisture after cleaning. For the insects and insect eggs an entoletor location might be used after the flour mixer where the entoletor kills the investations by impact.

Conditioning: The addition of correct amount of moisture to wheat in roller milling is necessary to insure proper milling. Moisture is adjusted so that the bran is tough enough to keep it from being broken up and this makes the separation between bran and endosperm easy during sifting. However, if the sorghum bran is removed as powder by dry abrasion milling, moisture tempering would not have the same relevance as in conventional "break and reduction" milling since the bran would be removed as powder by aspiration. The conditioning step would be optional.

Milling: For the present, a cheap and efficient milling process is needed to produce a flour within the purchasing power of the majority of people in East Africa. Such a method might involve debranning the grain and grinding up the polished grain in a one step procedure. For debranning, 20-25% of the weight of the brown seeded grain and less than 20% for the white sorghum can give a satisfactory product. A suitable pearler of an appropriate capacity such as the Cecoco rice polisher, a Japan make, would do the job.

At this stage, the germ is removed, dried and the oil recovered by pressure or solvent extraction. This produces two important by-products, sorghum oil, and sorghum oil meal; 100 Kg of sorghum grain yields about 2 Kg of oil. The oil, after further refining would be used for cooking purposes and the meal might be used as part of the Sambusa stuffing.

Whole polished kernels can be ground in a one-step procedure in mills similar to the Brabender Rapid Test mill, using stones; and preferably driven by a motor running on petrol.

Mixer: The sorghum flour obtained above would then be fed into a mixer and blended with all purpose wheat flour (often imported or donated), in proportions so that sorghum flour constitues 5-15% of the blend. Vitamin, and mineral additives and chemical preservatives would be added in the mixer at this stage to be thoroughly blended.

Packaging: The blended flour would then go to the packing machine where it would be packed in 2 Kg paper bags, coded and designated as Sambusa Flour.

Flour Shelf-Life: If the Sambusa flour stays in the mill, mill warehouse, wholesale grocer, retail grocer and homes for 1, 3-5, 5-10, and 2-14 days, respectively: a desirable shelf life for the Sambusa flour would be 14-35 days.

Proximate Analyses

Proximate analyses provide a good initial impression of the relative nutritive values of foods and allow a basis for comparison between different samples. Some of the chemical characteristics of the raw ingredients used in the Sambusa making are summarised in Table 8.

Crude protein values for polished sorghum are less than those for whole grain. On the other hand, the values for germ are much higher. This could be explained by the fact that abrasive milling removes the peripherial layers of the grain wherein the protein is concentrated in the germ and bran layers, this leaves the endosperm with less protein content. It was also observed that defatting the sorghum germ, soybeans, or Sambusa increases the protein levels in these products; 17.0 to 21.6% for the germ, 38.5 to 46.9% for the soybeans, and 21.5 to 30.4% for the Sambusa.

Crude fat values were approximately 29% less in the flour from the polished sorghum compared to those in original grain. With 0.5% fat in the flour from the polished grain, we would be assured of a flour of a very stable shelf life. In contrast to fat contents of the sorghum and its products, the soybeans and consequently the soybean Sambusa had relatively higher fat levels of 17.6 and 30% respectively. Consequently there would be

TABLE 8. PROXIMATE COMPOSITION OF SOME RAW INGREDIENTS AND COOKED SAMBUSA.

Whole Cereals and Mill Products	Moisture %	Crude Protein (a) %	Crude Fat %	Crude Fiber %	Ash %
Whole Sorghum, G766	12.0	10.8	2.7	1.7	1.4
Polished Sorghum	11.3	9.8	0.8	0.5	0.6
Sorghum Germ	7.3	17.0	19.3	1.7	11.2
Defatted Sorghum Germ	3.4	21.6	-[b]	-	-
Whole Soybeans	7.3	38.5	17.6	6.5	4.8
Defatted Soybeans	9.3	46.9	-	-	-
Wheat Flour	13.0	11.5	-	-	0.7
Soybean Sambusa	27.5	21.5	30.0	2.9	2.9
Defatted Sambusa	8.5	30.4	-	-	-

[a] Values on moisture-free basis; factors of N x 5.7 for wheat flour, and N x 6.25 for the remainder of the samples

[b] missing data

a need to apply some food preservation techniques for improving the shelf-life of the Sambusa.

Ash values were also less in the polished sorghum than in the orginal grain. In fact this value of 0.6% for sorghum compared favorably with that of 0.7% for US Government All Purpose Flour. As expected, the germ and the soybeans had high ash contents of 11.2 and 4.8% respectively.

Selected Nutrient Values

Comparative values obtained for selected nutrients analysed are shown in Table 9. Caloric content and protein and fat values for the Sambusa were determined and compared to published values for the currently popular US snacks, corn, potato and tortilla chips.

Protein content of the soybean Sambusa was between three and for times greater than that of any other chips available on market. One hundred grams of the Sambusa (approximately 2 Sambusas) would provide 21.5 grams of protein or about 33% protein of the adult male recommended daily allowance. Energy contents per 100 grams were 542, 479, 596 and 605 calories for the Sambusa, tortilla, corn and potato chips, respectively.

Many of the commercial snack foods available on market are derivatives of cereals. Their contribution to the diet is an overall increase in calories without appreciable increases in other nutrients. A nutritious snack food, with a protein value greater than that of chips currently on market - both in the US and East Africa - and having an appealing flavor and texture and appearance, would contribute to obtaining a balanced diet.

TABLE 9. CALORIC VALUES AND PROTEIN AND FAT CONTENT PER 100 GRAMS OF DRIED SAMPLE

Sample	Calories	Fat (gms)	Protein (gms)
Sambusa	542	30.4	21.5
[a]Tortilla chips	479	22.0	7.2
[a]Corn chips	596	34.0	7.2
[a]Potato chips	605	35.8	5.1

[a]Data from research by Judith S. Elliot. (15).

Amino Acid Analyses

Amino acid analyses for whole sorghum and polished sorghum; defatted sorghum germ and defatted soybeans are given in Table 10. These results show ~~that~~ the first limiting acid in cereals, lysine, to be lowest in both whole and polished sorghum (2.67 and 1.89). The lysine values for the germ and soybeans run quite high at 7.70 and 7.85 grams lysine per 100 grams of protein, respectively. This contrast is expected and points to the need of a study to evolve ways to utilize the germ and soybeans as stuffing in the Sambusa in an effort to improve the nutritional value of this food item. Of the non-essential amino acids, glutamic acid was present in the largest quantities: 16.29 (in the defatted germ) to 25.61 in the polished grain. Also, all samples contained proline, alanine and leucine in high concentrations.

TABLE 10. COMPARISON OF AMINO ACID COMPOSITION[a] OF WHOLE SORGHUM, POLISHED SORGHUM, DEFATTED SORGHUM GERM AND SOYBEANS

	SORGHUM AND ITS MILL PRODUCTS			SOYBEANS
Amino Acids[b]	Whole Sorghum	Polished Sorghum	Defatted Sorghum Germ	Defatted Soybeans
Lysine	2.67	1.89	7.70	7.85
Histidine	2.46	2.52	4.04	3.16
Ammonia	3.21	3.83	3.14	2.16
Arginine	4.18	3.15	9.39	7.84
Aspartic acid	6.98	5.92	8.86	12.59
Threonine	3.48	3.31	4.15	4.43
Serine	4.81	4.53	5.26	5.80
Glutamic acid	24.35	25.61	16.20	21.92
Proline	8.58	9.37	5.59	5.40
Glycine	3.31	2.65	5.59	4.89
Alanine	9.80	10.11	7.02	4.82
Valine	5.96	5.00	6.01	5.37
Isoleucine	4.08	4.74	3.64	4.85
Leucine	14.06	14.88	8.03	8.70
Tyrosine	4.09	3.47	3.44	4.31
Phenylalanine	5.32	5.26	4.72	5.52
Protein %[c]	10.8	9.8	21.6	46.9

[a]Grams of amino acid per 100 grams of protein

[b]Tryptophan, methionine and Half Cystine - not analysed

[c]% dry basis

Effect of the Polishing Action - Of particular interest was the effect, on the protein content and essential amino acids, of debranning the whole grain sorghum for 120 seconds in the Satake Mill. Compared to that of the whole grain, there was a 9.3% reduction in protein content, Table 11. Of the essential amino acids, only lysine showed a considerable reduction of 39.2%. The other essential amino acids which suffered relatively small reductions were phenylalanine 1.1%, threonine 4.9%, and valine 16.1%. We had expected reductions in leucine, isoleucine and histidine, but found increases of 5.8, 16.2 and 2.4%, respectively.

Effect of Water on the Dough Handling Properties

The amount of water used in the formula for Sambusa making showed its effect during the handling phase. Excessive levels (more than 45-48%) in the formula led to the formation of slack doughs. Such doughs were soft and would tear rather easily when flattened manually with the rolling pin. It would appear that at such water levels, a dough sheeting machine would be desirable. Moulding rolls, set at an appropriate clearance and manually or motor-driven, would ensure that a more uniform force was applied to sheet out the dough.

When water was less than 45%, the resulting dough was too stiff and required much labor to flatten it out. In addition, such doughs fried out too quickly before the subsequent stages of processing were completed.

But when the water level was 45-48%, the resulting dough was of good consistency and could easily be moulded.

TABLE 11. EFFECT OF POLISHING ON AMINO ACID COMPOSITION OF SORGHUM VARIETY G766W

	Amino Acids	% Reduction (-), or Increase (+) in
1.	Protein	-9.3
2.	Lysine	-29.2
3.	Phenylalanine	-1.1
4.	Threonine	-4.9
5.	Leucine	+5.8
6.	Isoleucine	+16.2
7.	Valine	-16.1
8.	Histidine	+2.4
9.	Ammonia	+19.3
10.	Arginine	-24.6
11.	Aspartic acid	-15.2
12.	Serine	-5.8
13.	Glutamic acid	+5.2
14.	Proline	+9.2
15.	Glycine	-19.9
16.	Alanine	+3.2
17.	Tyrosine	-15.2

Numbers 2-8:- Essential amino acids.

These dough consistencies would be easily identified by the experienced Sambusa processors. Measurement of the water absorption of these flours was checked by means of a farinograph which measured the force required to move the mixing blades through the dough mass at optimum consistency as a function of mixing. It was observed that the Sambusa dough was under mixed relative to bread dough and requires much less water.

Effect of Various levels of Sorghum Flour and Soybean stuffing on the Organoleptic Properties of the Sambusa

Values for objective measurements and palatability scores appear in Appendix, Tables 13-18. Throughout the remainder of the discussion, the treatment containing 0% sorghum flour will be referred to as A; 5% as B; 10% as C; and 15% as D.

Objective Measurements

Cooking Loss: The average cooking loss increased as the percentage of sorghum flour increased, Table 12 and Fig. 3. The dough became less extensible and less elastic as the percentage of sorghum flour increased, then with lowered elasticity there was increased surface area exposed to heat. This could have been a contributing factor to the increased cooking losses. However, the differences between the losses for treatments A and B were almost negligible, but the differences between other treatments were considerable.

Fat Absorption: Using the standard formula and frying the Sambusa weighing 100 gm (raw weight) followed by petroleum ether extraction, the

TABLE 12. MEAN VALUES FOR OBJECTIVE AND SUBJECTIVE EVALUATION OF THE SAMBUSA

Factors	Treatments[a] A	B	C	D
1. Cooking Loss	16.90	17.20	19.40	20.50
2. Color: Reflectance	23.09	20.85	17.85	14.42
Palatability:				
1. Appearance	6.3	6.4	6.4	6.3
2. Color	6.3	6.2	5.3	4.8
3. Texture	5.1	5.7	6.4	6.5
4. Flavor	6.4	6.1	5.3	4.1

[a]Treatment A = 0% Sorghum Flour

B = 5% Sorghum Flour

C = 10% Sorghum Flour

D = 15% Sorghum Flour

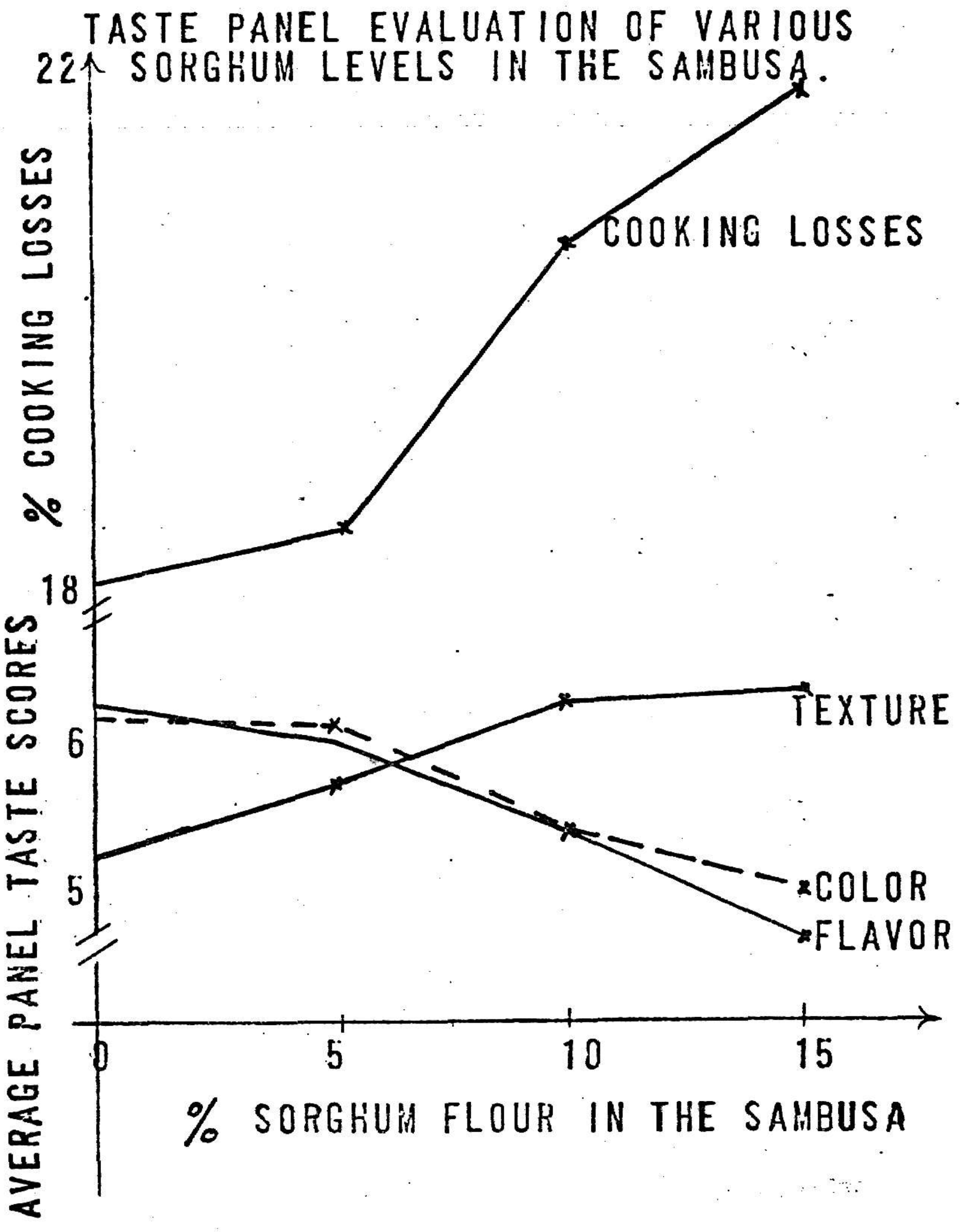


Figure 3. Effect of various sorghum levels on the Sambusa palatability.

fat absorption has been investigated to see the effects of :-

(a) various levels of sorghum in the flour blends

(b) frying temperatures

We found fat absorption under normal operating conditions to increase substantially with increasing amounts of sorghum flour in the flour blends. Treatments A, B, C and D had increased fat absorption in the following order, 2.0,2.7, 4.6 and 6.2% respectively. Experimentally we found that treatment A which normally gave a fat absorption of 2.0%, when fried at 375°F, had lower fat absorption of 1.7% when fried at a higher temperature of 400°F, and an increased absorption to 2.5% at a frying temperature of 350°F,. For treatments B, C and D increasing the frying temperature by 25°F produced the following absorption:- 1.9, 4.2 and 5.7% and lowering the temperature by 25°F gave the following absorptions:- 3.2, 5.5 and 6.6% respectively. There was a general increse in fat absorption with lowered temperatures and decreased absorption with increased temperatures, but the data were not consistent with proportionate increases in sorghum levels.

Fat absorption plays a relatively important role in adding richness of flavor, improving mouthfeel and eating quality. Sambusas with inadequate amounts of fat absorption acquire "dry" eating character, whereas too much fat absorption will leave a greasy feeling in the mouth. Comments from some members of the taste panel for treatment D as being greasy were confirmed by our observation of highest fat absorption in this product. Of the two phenomena in fat absorption - namely:- absorption and adsorption; adsorption probably contributed towards treatment D being singled out as "greasy". This was further supported by our visual examination of the D Sambusas compared with other treatments. The coarser granularity of the sorghum flour might be a contributing vector to increasing fat absorption with increasing levels of sorghum. Also since we were handling very thin doughs ($\frac{1''}{32}$), the likely major phenomena would be increased fat absorption by adsorption.

Color: An objective color measurement was made with the Gardner color-difference meter. In Table 12 the differences in reflectance attributable to sorghum flour are consierable in all cases. The values decreased indicating increased amount of light absorbed, with each percentage increment of sorghum flour following a downward pattern. The trend for less relectance with greater amounts of sorghum flour supports the concept that greater darkness is associated with increased percentage-of sorghum flour; which was of a light brown color. Thus a browner dough and product resulted as increasing amounts of sorghum flour were used.

pH: The pH of the dough decreased only slightly as the percentage of sorghum flour increased. It ranged pH 6.89 for treatment A to pH 6.83 for 100% debranned sorghum flour; but ranged from pH 6.89 for A to pH 6.75 for 100% whole sorghum flour. From this comes the assumption that whole sorghum flour (undebranned) is more acidic than the wheat flour. Acidity in whole sorghum flour could come from the tannins characteristically associated with brown seeded varieties of sorghum. Thus the increased acidity of the dough with increased whole sorghum flour could be related to the decreased elasticity of the dough since gluten strength would be decreased.

Subjective Measurements

There were certain limitations and difficulties involved in the organoleptic phase of the present study. During the prelimanary work it was found that each East African student had a different idea of a standard Sambusa and it was somewhat difficult to be unbiased in scoring. Their judgements were based on comparisons with the Sambusas eaten in their own homes or home cities, and it is known that Sambusas vary within East Africa itself and even from household to household in the same area. However, the control Sambusa (A) was frequently examined to reorient the panelists to the baseline. The scoring was based on a scale ranging from 7 (very desirable) to 1 (very undesirable).

Appearance: The average appearance scores did not vary much as the percentage of sorghum flour increased. However, some taste panel members objected to the under cooked appearance of the Sambusas with treatment A (highest reflectance value). Comments ranged from "raw" to "too white".

Color: The average color scores varied considerably with the treatments (Table 12), following a downward trend as the amount of sorghum flour increased. The main comment made by the judges was that treatment D was too dark. A few commented that treatment A was too light or pale. Apparently the sorghum flour was the contributing factor relating to the darkness of the sample. The very steep decline in average color scores (Fig. 3.) was ascribed to the increased levels of sorghum flour incorporated into the Sambusa.

Texture: Of special interest was the increase in texture scores with increasing amounts of sorghum flour. The average texture scores varied with the treatments in the following order: D, C, B and A, from the highest to the lowest (Table 12 and Fig. 3). Most judges made very favorable comments on the crust of D as being outstandingly crisp and crunchy. This favorable attribute in this Sambusa might be caused by the coarser granularity in the sorghum flour than in wheat flour. This was supported by the observation that the crispness was most pronounced in treatment D, containing 15% sorghum flour. It would be observed that with increasing cooking losses (mainly moisture), there were concurrent increases in crispness or mean texture scores.

Flavor: The average flavor scores varied with those for treatment A being the highest. Treatment A was preferred by some while others thought it had a slightly raw taste; B, C and D were generally well received, though there was a decrease in mean scores as the percentage of sorghum increased. In a number of tasting sessions, we deliberately cut down on the levels of spicing. In these instances, all treatments were ranked lower because of bitter taste associated with soybeans. Thus for the Sambusas to be acceptable a method that uses the right level of spices would mask the bitter principle. Since liberal amounts of curry powder and pepper are used in Sambusa making in East Africa, the bitter taste would be lost there in i.e in this method of preparation.

Soybean Supplementation and Effect on Flavor

Soybeans currently do not occupy a significant place in the agricultural economy of East Africa, but its use as a main crop has been recommended. Apparently, the greatest obstacles to the general use of soybean in food products are the bitter, beany flavor and objectionable odor and color of such products and their tendency to become rancid under ordinary storage conditions. Several methods have been developed to improve flavor, color and stability of soy products such as defatting, debittering, dehulling, and roasting. Moisture and heat improve flavor because interfering materials such as soyin and trypsin are proteins which are sensitive to heat. Since boiling and then frying is the most common method in East Africa for food preparation, soybeans could be prepared in the home and they would be a good means of supplementation to be used in the home situation to prepare Sambusas.

To summarise the subjective measurements, an evident relationship between texture and cooking loss appeared. The texture scores increased as the percent of cooking losses increased.

The comments of judges denoted similarity between objective and subjective scores for color. The reflectance (Rd) values indicated treatment A absorbed least light and D absorbed the most. The judges noted that treatment A was too pale and D too dark. The appearance scores may have been affected by color according to the comments of the judges.

Generally, there was little difference in average scores of the Sambusas for treatments A, B and C when considering appearance, color and flavor. For the most part treatment D was scored lower than any other treatment for most palatability factors. Thus, it appeared that treatments A, B, C and possibly D would be acceptable.

Further studies concerned with other levels of sorghum flour might be explored, using moulding rolls. Use of board and rolling pin permits only upto 15% sorghum flour in the dough to be handled. Varying the proportions of spices and salt to counteract the bitter soybean flavor might be investigated further.

CONCLUSIONS

Grain sorghum is among the oldest of cereals and is the world's third most important food grain, exceeded only by rice and wheat. It is the staple cereal for human consumption in large parts of East Africa. Inexpensive, high quality snack foods developed from sorghum and legumes have the potential of combating human malnutrition and for improving the quality of snack foods eaten by children and adults in East Africa.

An investigation of some of methods of processing the Sambusa and their potential influence on its quality have been conducted. The process of milling tended to reduce the nutritive value of the flour used in Sambusa making as measured by reductions in the protein and essential amino acid contents. The Sambusa-making qualities of different flour blends containing flour of sorghum with that of wheat have been studied. Wheat flour could be mixed with 5-15 percent of sorghum flour without adversely affecting its Sambusa making qualities or general palatability. Improper mixing and imbalances of water during dough make-up produced poor quality Sambusa.

The use of soybeans as a stuffing in the Sambusa was investigated. Our results indicated that the level of spices in the stuffing was particularly critical for the product to be acceptable. Otherwise, the soybeans proved to be the most nutritious ingredient in the Sambusa.

With respect to organoleptic judging it was found that the comments of the judges denoted similarity between objective measurements and subjective measurements for color, texture and cooking losses. Cooking losses always increased as the percentage of sorghum flour increased and so did the mean texture scores. But color, and flavor scores tended to decrease with increased sorghum flour. Use of a white kernelled sorghum grain instead of the dark brown variety studied here would yield Sambusas with better color acceptance.

Cereal and legume foods are an essential part of the traditional diets of many, if not most, of the developing world's people. Legumes are particularly important because they are high protein crops, with relatively well-balanced amino acids. They are also important because they often provide the only high protein part of the diet; together with the main cereal or starchy foods, legumes provide a reasonably balanced diet. It is not enough merely to mention these facts. But to pursue them in a significant and meaningful way is to give not only comfort and encouragement but also strength to those already engaged in and dedicated to alleviating these problems of food shortages and the resultant malnourishment.

To embark on a nutritional enrichment program, further research, basic and adaptive, is needed to evaluate the nutritional properties of the Sambusa and its techniques of processing; with due respect to consumer preferences, food habits and their socio-economic needs. If the present studies should stimlate interest in the underdeveloped science and technology of the Sambusa in an effort to improve the nutritional quality of the low grade cereal flours like sorghum, the author's objectives would have been worthwhile.

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APPENDIX

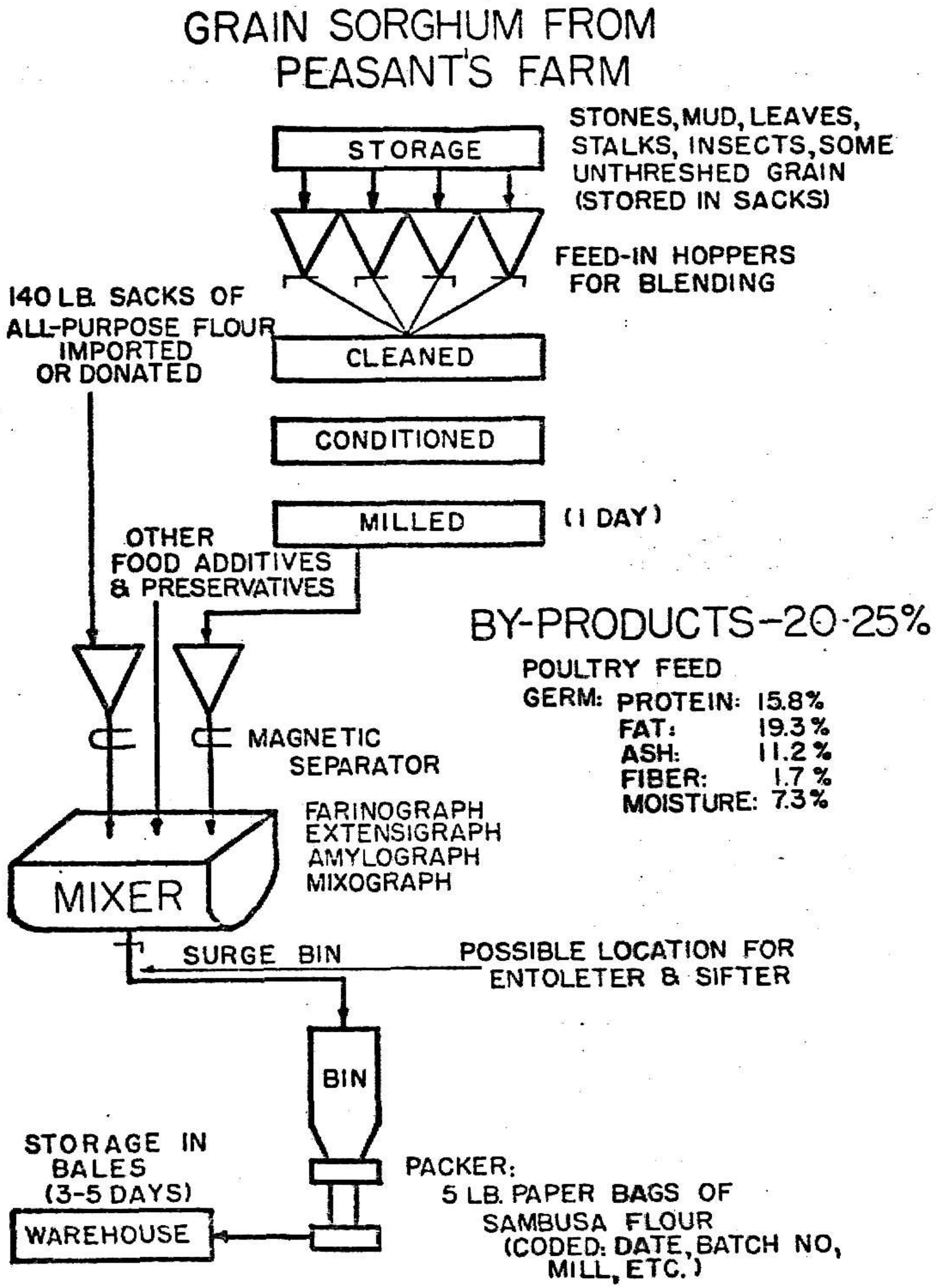

Fig. 4. A suggested schematic flow, flow for simple commercial milling for Sambusa flour blends.

TABLE 13. MEAN PERCENTAGE COOKING LOSS FOR DUPLICATE SAMPLES OF SAMBUSA

Sample	Treatment[a]			
	A	B	C	D
1	16.24	17.10	19.27	19.14
2	17.20	16.66	10.27	20.40
3	16.80	16.05	21.45	20.00
4	17.89	16.99	19.38	20.07
5	16.76	17.97	18.70	20.34
6	16.94	16.56	19.40	21.48
7	16.97	17.16	18.30	21.45
8	16.52	17.83	18.71	20.27
9	16.95	17.96	18.83	20.98
10	16.42	17.38	19.77	21.27
Av.	16.90	17.20	19.40	20.50

[a]Treatment: A = 0% Sorghum flour

B = 5% Sorghum flour

C = 10% Sorghum flour

D = 15% Sorghum flour

TABLE 14. COLOR: REFLECTANCE (Rd) VALUES FOR SAMBUSA[a]

	Treatment[b]			
Sample	A	B	C	D
1	22.0	20.0	16.6	14.3
2	22.2	21.4	13.6	14.0
3	21.9	20.4	18.2	16.8
4	21.0	19.1	16.5	12.5
5	25.2	20.7	23.4	15.4
6	22.4	19.7	24.2	16.5
7	25.2	23.6	15.9	12.0
8	22.6	19.4	14.2	14.9
9	23.4	22.5	18.9	12.6
10	25.0	21.7	17.0	15.2
Av.	23.1	20.9	17.9	14.4

[a]Gardner Color-Difference Meter measurement

[b]Treatment: A = 0% Sorghum flour

B = 5% Sorghum flour

C = 10% Sorghum flour

D = 15% Sorghum flour

TABLE 15. APPEARANCE SCORES FOR THE SAMBUSA[a]

Judge	Treatment[b]	Period 1	2	3	4	5	Av.
1	A	7	7	7	6	6	6.6
	B	7	6	7	6	7	6.6
	C	7	7	7	7	7	7.0
	D	7	6	7	6	7	6.6
2	A	6	7	7	6	6	6.4
	B	6	6	7	7	7	6.6
	C	6	6	7	7	6	6.4
	D	7	6	7	7	7	6.8
3	A	6	6	6	7	6	6.2
	B	6	6	6	7	6	6.2
	C	6	6	6	7	6	6.2
	D	6	7	6	6	6	6.2
4	A	5	4	7	6	5	5.4
	B	6	5	5	6	7	5.8
	C	7	5	5	6	7	6.0
	D	5	4	6	6	7	5.4
5	A	7	7	6	6	7	6.6
	B	7	6	7	7	7	6.6
	C	6	7	7	6	7	6.6
	D	6	6	7	7	7	6.6

[a]Range: 7 (very desirable) to 1 (very undesirable)

[b]Treatment: A = 0% sorghum flour; B = 5%; C = 10%; D = 15%.

TABLE 16. COLOR SCORES FOR SAMBUSA[a]

Judge	Treatment[b]	Period 1	2	3	4	5	Av.
1	A	7	6	6	7	6	6.4
	B	6	6	6	6	7	6.2
	C	5	5	4	4	3	4.2
	D	5	5	5	3	3	4.2
2	A	6	7	7	7	6	6.6
	B	5	7	6	7	6	6.2
	C	6	6	6	7	5	6.0
	D	4	5	6	7	5	5.4
3	A	6	7	7	7	7	6.8
	B	6	6	6	6	7	6.2
	C	5	5	4	3	5	4.4
	D	4	5	3	3	3	3.6
4	A	5	4	7	6	7	5.8
	B	6	7	6	7	6	6.4
	C	4	6	6	6	6	5.6
	D	4	6	5	5	6	5.2
5	A	6	6	6	6	6	6.0
	B	6	6	6	6	6	6.0
	C	6	5	6	6	6	5.8
	D	6	5	6	5	5	5.4

[a]Range: 7 (very desirable) to 1 (very undesirable)

[b]Treatment: A = 0% sorghum flour; B = 5%; C = 10%; D = 15%.

TABLE 17. TEXTURE SCORES FOR SAMBUSA[a]

Judge	Treatment[b]	Period 1	2	3	4	5	Av.
1	A	5	4	5	6	5	5.0
	B	6	5	7	6	6	6.0
	C	6	6	7	7	6	6.4
	D	6	7	7	7	7	6.8
2	A	6	3	5	5	5	4.8
	B	6	6	7	7	5	6.2
	C	7	7	6	7	6	6.6
	D	7	7	7	7	6	6.8
3	A	7	5	6	6	6	6.0
	B	6	6	5	7	6	6.0
	C	6	6	6	6	6	6.0
	D	4	5	7	5	6	5.4
4	A	5	3	5	5	6	4.8
	B	5	5	6	5	5	5.2
	C	6	6	7	7	6	6.4
	D	6	7	7	7	7	6.8
5	A	5	4	4	5	6	4.8
	B	5	5	6	4	5	5.0
	C	6	6	7	7	6	6.4
	D	7	6	7	7	7	6.8

[a]Range: 7 (very desirable) to 1 (very undesirable)

[b]Treatment: A = 0% sorghum flour; B = 5%; C = 10%; D = 15%.

TABLE 18. FLAVOR SCORES FOR SAMBUSA[a]

		Period					
Judge	Treatment[b]	1	2	3	4	5	Av.
1	A	6.0	6.0	6.0	6.0	6.0	6.0
	B	5.0	6.0	5.5	6.0	5.5	5.8
	C	5.0	5.0	6.0	5.0	4.5	5.1
	D	4.5	4.0	3.5	3.5	4.0	3.9
2	A	6.0	6.0	6.0	6.5	6.0	6.1
	B	5.5	6.0	6.0	6.3	6.0	6.0
	C	4.5	4.0	6.0	4.5	3.0	4.4
	D	5.5	2.5	4.0	4.0	3.0	3.8
3	A	6.5	7.0	7.0	6.5	7.0	6.8
	B	6.0	7.0	6.5	7.0	7.0	6.7
	C	6.0	6.5	6.0	6.0	6.0	6.1
	D	6.0	5.0	4.0	4.0	4.5	4.7
4	A	7.0	6.5	5.5	7.0	6.5	6.1
	B	6.0	6.0	5.0	6.5	6.0	5.8
	C	6.5	4.0	6.5	6.5	6.0	5.9
	D	5.0	6.0	4.5	5.0	4.5	5.0
5	A	7.0	7.0	7.0	7.0	7.0	7.0
	B	6.5	7.0	6.5	6.5	6.5	6.6
	C	5.0	5.0	5.5	5.0	5.0	5.1
	D	5.5	4.0	4.5	4.0	4.5	4.5

[a]Range: 7 (very desirable) to 1 (very undesirable)

[b]Treatment: A = 0% sorghum flour; B = 5%; C = 10%; D = 15%.

EFFECTS OF USE OF SOYBEANS AND SORGHUM FLOUR ON THE SAMBUSA PALATABILITY

by

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AN ABSTRACT OF A MASTER'S THESIS

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requirements for the degree

MASTER OF SCIENCE IN

FOOD SCIENCE

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Manhattan, Kansas

1974

There is a growing need in the developing countries today for the provision of food, in quality and quantity for the health and normal development of man. This need calls for attention to the necessity of re-evaluation of the existing methods of food processing and technology. To this end, the effects of some of the more important factors on the quality of the Sambusa - a snack food item whose crust is normally made from all purpose wheat flour and whose stuffing may be rice, minced meat or beans- have been investigated. Other effects investigated and compared were:-

(a) the substitution of 0, 5, 10 and 15% sorghum flour for part of wheat flour.

(b) the use of whole soybeans as a stuffing in the Sambusa.

The Sambusas, prepared from our recipe, were evaluated objectively and subjectively.

The data from the studies indicated that the process of milling sorghum to obtain the flour leads to a reduction in its protein and amino acid contents. Nutrient losses due to milling could be accounted for by the fact that a large proportion of the bran and germ is discarded. In addition to this, some material losses occur as dust during grinding, sifting and weighing.

The cooking losses, fat absorptions and texture scores always increased as the percentage of sorghum flour increased. But the pH, appearance, color and flavor scores tended to decrease as the percentage of sorghum flour increased. When the level of spices in the Sambusa was halved, all the Sambusas were scored lower than those containing the normal level, and generally were not well received. Overall, there was above average response to changes in the level of sorghum flour for all palatability factors scored.