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CASSAVA (*MANIHOT ESCULENTA* CRANTZ) FLOUR FORTIFICATION WITH SOYBEAN FLOUR

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Claver R. Temalilwa

March 1980

141630?

DEDICATION

The author dedicates this thesis to his wife, son and daughter. He hopes that his work will help in a small way to make more effective use of food resources in not only his country but the entire world.

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ABSTRACT

This study was conducted to achieve the following objectives: (1) to determine the physical and sensory attributes of the doughs prepared from cassava in which soybean flour was substituted for different amounts of cassava flour; (2) to determine the optimum level of soybean flour that can be substituted for cassava in the doughs; and (3) to evaluate the nutritional value of different mixtures of cassava and soybean flours.

The cassava flour had a protein content of 2.09%, and the commercial defatted soybean flour had a protein content of 53.78% on an air-dried weight basis.

The hydrocyanic acid content of the cassava flour was 5.58 mg of acid/100 g of the flour on the air-dried weight basis. At this level of the acid, a human adult male weighing 50 kg will have to eat about 500 g of the flour mixture to reach the lethal dose of 50-60 mg of hydrocyanic acid. Also, addition of soybean flour to cassava flour has a diluting effect on the acid. Therefore, all mixtures containing soybean flour had less than 5.58 mg of hydrocyanic acid/100 g of flour.

Samples of dough prepared from the different mixtures of cassava and soybean flours were softer than samples prepared from cassava flour alone (control). In order to standardize the consistency of doughs prepared from

mixtures of cassava and soybean flours to that of dough prepared as the control, the amount of water added was reduced from that used to prepare a control dough. The following amounts of water were added to 80 g of mixtures containing the different percentages of soybean flour: 250 ml for 0% soybean flour (control); 242.5 ml for 5% soybean flour; 240.5 ml for 10% soybean flour; 233.0 ml for 15% soybean flour, and 227.8 ml for 20% soybean flour.

Soybean flour caused cassava dough to darken and become more red and more yellow. At the 20% soybean flour level, the dough was unacceptable to the panel, partly due to yellow color.

A panel of ten students from Tanzania, Kenya, Zambia, Nigeria, and Ghana evaluated the samples of dough for appearance, texture, and eating quality. Considering the three variables tested by the panel, the dough containing 15% soybean flour was the most acceptable. At his level of soybean flour, the dough was preferred to the control dough. At the 20% level of soybean flour, scores for appearance and eating quality were lower than those of the control dough (see Appendix B). At the 20% level of soybean flour, appearance and taste were unacceptable to the panel, but the texture was acceptable. The dough with 15% soybean flour was scored above 5.0 (<u>like moderately</u>) for appearance, texture, and eating

quality. The control sample dough was scored 4.93 for appearance, 2.60 for texture, and 3.63 for eating quality.

Doughs of all the mixtures were deficient in all amino acids but more so for the sulfur-containing amino acids. The dough with 15% soybean flour (most preferred by the panel) provided approximately 30% of the levels of amino acids specified in the FAO Provisional Pattern.

The protein efficiency ratio (PER) of the cassava-soybean flour mixture (10.56% protein but calculated at 10% protein) was 1.55 with casein serving as the reference protein (adjusted PER for casein = 2.5). The unadjusted PER value for casein was 2.91.

The rats fed flour mixtures containing 0% and 5% soybean flour lost weight during the experimental period. During the same period, the mixture containing 10% soybean flour did not cause any weight gain. The 15% and 20% soybean flour mixtures supported weight gain.

This study shows that 15% soybean flour can be added to cassava flour without adversely affecting acceptability of the dough. At this level of soybean flour, the dough was darker, slightly more yellow, and slightly more red than the control dough. Appearance, texture, and eating quality of the dough were acceptable.

The protein content of the cassava flour was increased from 2.09 to 9.85 by adding 15% soybean flour. The amino acid levels of this mixture were below the levels recommended by FAO.

The energy content of the mixture containing 15% soybean flour is sufficient to meet the needs of a "reference" man and a "reference" woman.

Preparing cassava flour for food by sieving, as practiced by East Africans, lowers the protein content of the flour. About 21% of the nitrogen in the cassava meal was non-protein nitrogen.

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CHAPTER I

INTRODUCTION

The cassava (Manihot esculenta Crantz) root is an important source of food in tropical countries. The root is the seventh most important staple food source in the world (24). In 1977, two-thirds of the world's production of cassava (343.1 million metric tons) was produced in Brazil, Indonesia, Zaire, Nigeria, and India (24). In the same year, Tanzania produced 4 million metric tons of this crop which was used entirely for food (24,39). As in other African countries, cassava produced in Tanzania is eaten largely in the form of dough.

Sweet and bitter types of cassava are grown. The sweet variety is cultivated for food, while the bitter type, which has a high starch content, is reserved for industrial starch production (6,27). The bitterness is associated with the cyanogenic glucoside linamarin which undergoes hydrolysis to yield hydrocyanic acid. The acid is toxic to humans and animals (8,27,44). The sweet type of cassava has a relatively low level of linamarin.

Experience with cassava-based foods has shown that residual amounts of linamarin are not highly toxic if the enzyme system responsible for hydrolysis of linamarin to hydrocyanic acid has been inactivated by cooking (17).

The eating of cassava has an adverse action on the thyroid glandand may be responsible for goiter in the cassava-eating areas of Nigeria (48). Also, circumstantial evidence has associated ataxic neuropathy (a syndrome characterized by lesions of the skin, mucous membranes, optic and auditory nerves, spinal cord and peripheral nerves) with excessive cassava intake (48).

Cooke et al. (16), studying the effect of simple processing on the cyanide content of cassava chips, found that dehydration of cassava chips at 46.6° C. removed the free cyanide rapidly and 29% of bound cyanide. According to Bolhis (9), 50-60 mg of hydrocyanic acid is a lethal dose for an adult human male weighing 50 kg. United States legislation requires that Phaseolus lunatus (lima beans) used for human consumption must contain not more than 20 mg of the acid per 100 g of food (41).

Cassava is deficient in the quantity of protein. The small amount of protein present is of low quality. The protein content varies from 0.7 to 2.6%, depending on the variety and growing conditions. A major portion of the total nitrogen exists in simple, nitrogenous, non-protein compounds (30,54). According to literature values, cassava meal protein has higher amounts of lysine, arginine, aspartic acid, threonine, and alanine than wheat protein. The limiting amino acids are the sulfur-containing amino acids (13,51).

Carbohydrates make up 64-72% of the dry matter of the cassava root. The root is an excellent source of energy for over 300 million people on three continents. The vegetable is a rich source of calcium, vitamin C, and nutritionally significant quantities of thiamine, riboflavin, and niacin (31). A large portion of these nutrients is lost during processing of the root into flour.

Since the root is a staple food source, the flour can be used as a carrier of superior sources of protein such as soybean protein. Some acceptable food products fortified with soybean protein have been developed to increase the protein content of the staple foods. These include Incaparina in Central America (10,52), Siderele in Indonesia (23), ProNutro in South Africa (53), Soy-Ogi in Nigeria (1), and Maize-Soy blend in Tanzania (43). In Tanzania, bananas, corn, and cassava are the major staple foods. These foods are important in determining the nutritional status of the people because of their low protein content. Childhood and sometimes maternal protein deficiency diseases have been attributed to consumption of relatively large amounts of cassava and bananas (39).

In Tanzania, plans are underway to enrich cassava flour and/or composite flours. Plain cassava flour has been produced commercially (39). According to Wyllie and Huxley (58), the Tanzania School of Agriculture, Forestry

and Veterinary Science has placed emphasis on improving cassava production with emphasis on maximizing the protein content of the plant including the root. Also, the government has reactivated soybean production which dwindled in the 1960's. The project is aimed at producing soybean flour and oil for local use (39).

This study was undertaken to investigate the effect of defatted soybean flour on the appearance, texture, and acceptability of a cassava-soybean dough; to evaluate the proteins in cassava-soybean dough; to evaluate the proteins in cassava-soybean mixtures; to determine the protein efficiency ratio and the limiting amino acids; and to ascertain the maximum level of soybean flour which can be added to cassava flour without affecting acceptability of the resultant dough.

CHAPTER II

REVIEW OF THE LITERATURE

I. USE OF CASSAVA AS HUMAN FOOD

Cassava (Manihot esculenta Crantz) is one of the world's most important staple food crops and provides a major source of energy to about 300 million people (46). The plant is known by a variety of names depending on the locality: ubi kettella or kapse (Indonesia); manioca, rumu or yucca (Latin America); mandioca or aipin (Brazil); manioc (Madagascar and French-speaking Africa); tapioca (India and Malyasia); cassava and sometimes cassada (English-speaking regions in Africa, Thailand, and Sri Lanka) (27). Cassava is a perennial shrub which may be cultivated within 30° of the equator. A single plant may produce 5-15 tuberous roots which average 2-5 kg. (6). Cassava is produced in more than 80 countries, but two-thirds of the world's production (343.1 million metric tons) comes from Brazil, Indonesia, Zaire, Nigeria, and India (24).

Advantages of cassava over other staple food crops include the following: the vegetable has a higher productivity in terms of calories per unit land per unit time (19). According to Coursey and Haynes (18), cassava can produce 250×10^3 calories/ha/day as compared to 176×10^3 calories of rice, 110×10^3 calories of wheat, 200×10^3

calories of corn, and 114×10^3 for sorghum. Like other root crops, cassava has a high biological efficiency as a food producer. The crop can be planted anytime of the year, and the roots can be held in the ground for several months without harvesting. The cost of cassava production is relatively low due to factors such as low labor requirements, ease of cultivation, low investment and resistance to plant pests. The plant is well adapted to a wide range of ecological conditions (31).

The most important use of cassava is for human food, and in most of the cassava growing areas, it is an important staple. Coursey and Haynes (18) have estimated the contribution of root crops to world diets at 6% for the Near East, 11% for the Far East, 15% for Latin America, and 29% for Africa. Cassava contributes 10% of the daily global caloric needs.

According to FAO Production Yearbook (24), Africa produces 44.3 million metric tons of cassava annually and a large percentage of this is eaten in the form of a dough. Cassava roots are processed into a meal which is mixed with boiling water and stirred continuously to make a dough of desired consistency. The dough, known as stiff porridge, is eaten with stew of vegetables, fish, or beef. Cassava forms the staple food of the low income groups of the population (11). The incidence of protein malnutrition is particularly high among children subsisting on cassava

diets. Nutritional surveys in Tanzania show widespread protein calorie malnutrition averaging 25% among the vulnerable groups, especially the children under five years of age (35,38). This has been attributed to low protein intakes, its distribution within the family, and large carbohydrate consumption, especially cereals and root crops such as cassava.

II. PREPARATION OF CASSAVA ROOT FOR FOOD

The method of preparation of cassava root depends on the product desired. Most steps involved in traditional methods of processing cassava root tubers into various cassava products aim at reducing the concentration of linamarin and hydrocyanic acid to levels harmless to humans, and to improve the palatability of the roots. The steps may include peeling, fermentation, pressing, roasting, and cooking (33). Cassava flour may be prepared from sun-dried root chips by pounding in a mortar (42). In Tanzania, the above method is used commercially. Dried cassava chips are sold to the central processing plant where the flour is milled, packed, and distributed to the consumers. Cooke and Maduagwu (16), studying the effects of simple processing on the cyanide content of cassava chips, found that all processes rapidly removed free cyanide (8-12% of the total cyanide) from the chips, and that air-drying at 46.5^{o} C removed 29% of the bound cyanide.

III. NUTRITIVE VALUE OF CASSAVA ROOT

Cassava is a rich source of calories but is deficient in protein, fat, and some vitamins and minerals (21,50). The average crude protein content of cassava varies from 0.7 - 2.6%. A major portion of the total nitrogen is simple nitrogenous compounds (30,54). Cassava protein is comparable to rice protein in digestibility with a biological value of 48%, but is lower than that of wheat (13). Compared to wheat, cassava flour has a higher amount of lysine, arginine, aspartic acid threonine, and alanine. Cassava is deficient in sulfur-containing amino acids and trytophan (12,51).

Cassava meal contains the following amino acids expressed as g/16 g N: lysine, 4.14; methionine, 1.33; cystine, 1.44; total sulfur-containing amino acids, 2.72; tryptophan, 1.15; threonine, 2.64; isoleucine, 2.80; leucine, 3.92; phenylalanine, 2.50; tyrosine, 1.60; total aromatic amino acids, 4.10; valine, 3.34; arginine, 10.93; histidine; serine, 3.26; glutamic acid, 16.14; glycine, 2.56; aspartic acid, 6.50; alanine, 3.76; and proline, 2.75 (22,54). The low concentration of sulfur-containing amino acids is due particularly to the involvement of cysteine and cystine in cyanide detoxification (48). The cyanide is mainly detoxified by conversion to thiocyanate, and in the process it reacts with cystine and cysteine. The amount and quality of cassava protein

may be altered significantly by processing, and the alteration of protein has implications for specific nutritional problems in Africa, including malnutrition.

Most of the dry matter in cassava roots consists of carbohydrates, 64-72% of which is starch. Amylose and amylopectin together make up approximately 99% of the cassava starch (30). Sucrose makes up as much as 17% of the carbohydrate content in the sweet varieties. Cassava has approximately 0.5% ether extractable material, but the type of fatty acids in cassava is unknown.

Cassava roots are rich in calcium and vitamin C, and nutritionally significant quantities of thiamine, riboflavin and niacin. According to Jones (31), 1 kg of fresh cassava roots could contribute 66% calcium, 125% iron, 58% thiamine, 83% riboflavin, 40% niacin, and 1600% vitamin C of the daily requirements of an active adult living in the tropics. A large percentage of these nutrients is lost in the process of converting the roots into flour such that fortification is indispensable in populations where cassava is a staple food.

IV. TOXICITY OF CASSAVA ROOT

The hydrocyanic acid (HCN) toxicity of cassava resulting from the presence of cynogenic glycosides has been described by several authors (7,8,9,17,31,41,44,46, 47,48,55). The glycosides are responsible for the bitter

taste of cassava, and upon hydrolysis they yield HCN and glucose. The glycoside content varies with the variety of cassava and the type of soil where it is grown. The acid tends to be higher when cassava is produced on poor soils, in dry conditions, and under potassium deficiency.

In sweet varieties of cassava, which are reserved for food, the major portion of the acid is located in the cortex, while in bitter varieties, the acid is uniformly distributed in all parts of the root. The latter type is reserved for starch production (6). "Bitter" cultivars of cassava are usually higher in HCN content than the "sweet" ones. According to Coursey (17), the normal range of cyanogen content is 5-400 parts per million (ppm) calculated as mg HCN/kg of cassava (fresh weight), but occasionally samples with concentrations as low as 10 mg/kg or over 2000 mg/kg have been reported. Most commonly HCN content falls between 30 and 150 mg/kg. Therefore, when processing cassava for food, the cortex must be removed completely and the flesh must be washed thoroughly. In the United States, legislation limits the concentration of HCN in Phaseolus lunatus (lima beans) for human consumption to 20 mg/100 g of food.

Wilson (55) and Osuntokun (48) have shown that there is only circumstantial evidence linking human disease with chronic cyanide exposure. According to these authors, ataxic neuropathy (a syndrome characterized by lesions

of the skin, membranes, optic and auditory nerves, spinal cord, and peripheral nerves) of West Africa is probably multifactorial. Large consumption of cassava may be harmful to the body due to lack of protein and riboflavin which is essential for incorporation of cyanide into the single carbon unit metabolic pool. The authors reported also that the prevalence of goiter was closely related to cassava consumption.

V. NUTRITIVE VALUE OF SOYBEAN PROTEIN

The nutritive quality of food proteins depend largely on the relative proportions of the essential amino acids it contains. Soybean protein is an ideal supplement for correcting the amino acid deficiencies of protein in various food systems (32).

Use of soybean protein in food systems increased from 5-7% per year in 1973 to about 10% in 1975 (4,37). Soybeans can be used in several forms depending on the food system. Commercial forms of soybean products and their analyses are given in Table I (28). Table II presents the essential amino acid content of soybean proteins (45,46). The amino acid pattern is approximately comparable to that recommended by the Food and Agriculture Organization of the United Nations, except that the sulfur-containing amino acids content is lower in soybean protein (25). Also, soybeans are an excellent

TABLE I

COMMERCIAL FORMS OF SOYBEAN PRODUCTS AND THEIR ANALYSES

Form of Soybean Product	Protein, %	Fat, %	Moisture, %
Flours and grits			
Full-fat	41.0	10.5	6.0
High-fat	46.0	14.5	6.0
Low-fat	52.5	4.0	6.0
Defatted	53.0	0.6	6.0
Lecithinated	51.0	6.5	7.0
Concentrates	66.0	0.3	6.7
Isolates	92.8	0.1	4.7

Source: Reference 28.

TABLE II

ESSENTIAL AMINO ACID CONTENT FOR SOYBEAN PRODUCTS

Amino Acid	Defatted Flour	Concentrate	Isolate
		g/16 g Nitrogen	
Lysine	6.9	6.6	5.7
Methionine	1.6	1.3	1.3
Cystine	1.6	1.6	1.0
Tryptophan	1.3	1.4	1.0
Threonine	4.3	4.3	3.8
Isoleucine	5.1	4.9	5.0
Leucine	7.7	8.8	7.9
Phenylalanine	5.0	5.3	5.9
Valine	5.4	5.0	5.2

Source: References 45, 56.

source of some minerals and vitamins. In light of this, soybeans can be used effectively to supplement diets of populations whose staples (such as cereals, cassava, and other root crops) are deficient of these nutrients.

VI. CASSAVA ENRICHMENT

In countries where cassava is a staple food, protein inadequacy is a common problem (48,57). In these areas efforts are being made to explore all the available food resources in an attempt to meet the protein requirements of the people (25). Cassava, a common staple food, can be used as a carrier of vegetable proteins which otherwise may have been unacceptable.

The use of cassava in breadmaking has been reported (27). According to Grace (27), flours used in bread-making included cassava flour and cassava starch flour and sources of protein including full-fat and defatted oilseed flours such as cottonseed, soybean, and peanut, as well as fish meal. The quality of protein of cassava-soy and cassava-peanut breads is higher than that of common wheat bread. Blends of wheat, cassava, and soy promise no manufacturing difficulties and acceptable products (49).

According to Okezie (47), gari, a traditional cassava product in West Africa, may be improved nutritionally by the addition of soy protein concentrate and whey. In 1972, the Brazilian National Institute

for Social Security (INPS) considered producing a fortified cassava product consisting of the cassava flour and fish protein concentrate (FPC), soy protein isolate, food yeast, or casein for mass feeding (6).

Soy flour has been used successfully in basic foods worldwide: Incaparina in Central America (10,52), Siderele in Indonesia (23), ProNutro in South Africa (53), Soy-ogi in Nigeria (1) and Maize-soy blend in Tanzania (43). Research on incorporating soybean flour and cheese in tortillas, a basic component of the Mexican diet was successful (15). Also, Del valle and Perez-Villasensor enriched tortillas with soy proteins by lime cooking corn and soybean mixtures (20). Since cassava and soybean proteins are deficient in sulfur-containing amino-acids (13,19), care must be taken to fortify the products so that their amino acid pattern is comparable to that of the FAO Provisional Pattern (19,25,49).

CHAPTER III

MATERIALS AND METHODS

I. SOURCE OF CASSAVA AND SOYBEAN FLOUR AND PREPARATION OF CASSAVA FLOUR

A sweet variety of fresh cassava roots (Manihot esculenta Crantz.) was obtained from Mr. Roy Champagne, 18710 S.W. 288th Street, Homestead, Fla. 33030. About 600 lbs. of the roots were shipped by bus to Knoxville. Upon receipt, the roots were refrigerated at 2-3° C and held until they were processed. The roots were processed three days after harvest.

A ten pound lot of defatted soybean flour (I-200, Lot No. SFD 1392C) was provided by the Protein Division, A.E. Staley Manufacturing Co., Decatur, Ill. 62525. The flour had 53.78% protein, air-dried weight basis.

The cassava roots were washed in running water to remove adhering soil. The roots were grated into thin slices using a Hobart Food Chopper (Model 84142). The grating plate had holes of 0.794 cm (5/16 in.) in diameter. Grated cassava roots were dried in a forced-air dehydrator at 60° C. The dried cassava chips were ground in a Viking hammer mill to pass a 30 mesh (0.589 cm) sieve. The flour was stored at 1° C until analyzed and prepared into a dough or used in diets for feeding laboratory rats.

II. CHEMICAL ANALYSIS OF CASSAVA AND SOYBEAN FLOURS

A. Moisture

Moisture content of the cassava and soybean flours was determined by the vacuum oven method (5). Triplicate samples of 5 grams were dried to constant weight at 100 $\pm$ 2° C and 200 torr (22 inches Mercury vacuum).

B. Crude fat

Oven dried cassava and soybean flours were extracted continuously with petroleum ether for 5 hours to determine the lipid content. Three, 2-g samples of each material were analyzed according to AOAC(5).

C. Crude protein

Air dried cassava and soybean flours, and cassava meal were analyzed for protein content (%N x 6.25) by the modified Kjeldahl method according to AOAC(5). Each material was tested in triplicate using 2-g samples of cassava flour or 0.5-g samples of soybean flour.

D. Crude fiber

Crude fiber content of cassava and soybean flours was analyzed according to AOAC(5). Each material was tested in triplicate using 2-g samples.

E. Ash

The percentage of ash in cassava and soybean flours was determined according to AOAC(5). Two-g samples were

ashed to constant weight in a muffle furnace at 525° C. Samples were analyzed in three replications.

F. Gross caloric energy

The caloric content of cassava and soybean flours was determined by an Oxygen Bomb Calorimeter (Parr Instrument Co., Moline, Ill.)(2). Approximately 1g of dried sample was analyzed in triplicate.

G. Hydrocyanic Acid level of cassava flour

The percentage of hydrocyanic acid on air-dried basis was determined by alkaline distillation (5). Three, 10-g samples of cassava flour were allowed to stand in 200 milliliters of water for 4 hours to extract the acid. The hydrocyanic acid was distilled into a dilute solution of sodium hydroxide. The acid was determined by titration of the alkaline solution with a standardized solution of silver nitrate (1 ml of 0.2N $AgNO_3$ ≡ 1.08 miligrams HCN).

H. Determination of non-protein nitrogen

Non-protein nitrogen was determined as follows: 20 g of cassava meal was suspended in 100 ml of distilled water and the mixture was shaken on wrist-rocker for 1 hour to extract the proteins and other nitrogenous compounds. To the above mixture 5 g of trichloroacetic acid (TCA) was added and the mixture was shaken for 1 hour to precipitate the protein. After centrifuging the above mixture, 10 ml

of the supernatant liquid was analyzed for nitrogen by the modified Kjeldahl method according to AOAC (5). The blank sample contained 100 ml of distilled water and 5 g of TCA. Triplicate samples were analyzed.

III. PREPARATION OF DOUGH CONSISTING OF CASSAVA AND SOYBEAN FLOURS

The dough for the control samples was prepared by adding cassava flour (80 g) to 50 ml of boiling water. This mixture yielded a dough with a consistency similar to that prepared by people who eat the product.

A composite flour was prepared by adding sufficient amounts of soybean flour to cassava flour to yield mixtures containing 5%, 10%, 15%, and 20% soybean flour on the air-dried weight scale.

Consistency of the doughs prepared from the composite flour was manipulated so that they had a consistency similar to that of the dough of the control samples. To accomplish this, three levels of water (one above and one below the control level) were added to a given flour mixture, the doughs were prepared, and firmness was measured. Linear regression analysis was used to calculate the amount of water needed to provide the desired consistency.

IV. MEASUREMENT OF DOUGH CONSISTENCY

The Instron Food Testing Machine (Model 1132) was used to measure the force expressed as kilograms required

to extrude a 100-g sample of dough (3). The Kramer extrusion cell and a 50-kg capacity load cell were used. The cross-head speed was set at 10 centimeters (cm.) per minute. Two readings were made on each of three samples of dough containing each level of soybean flour.

V. COLOR DETERMINATION OF THE DOUGH

Doughs with different levels of soybean flour and having a consistency similar to that of the control sample were measured for color. Measurement was made with the Hunter Color Meter (Model D25D2M) and the L, "a," and "b" values were recorded. The instrument was standardized against a white tile (Hunter C2-136). For measurement, the sample was placed into a cuvette (6.4 cm. diameter x 5.7 cm. height) with an optical glass bottom. Two readings were made on each of three samples of dough containing each level of soybean flour.

VI. SENSORY EVALUATION OF THE DOUGH

Samples of dough from the five treatments (cassava flour-soybean flour combinations) as previously described in Section II were served to a panel of ten members. The panel consisted of African students at the University of Tennessee, Knoxville, who are familiar with the cassava product as prepared in their homelands. Each panelist was

provided with approximately 5g of sample. Water was provided for rinsing the mouth between the testing of samples. The evaluation was replicated three times with one replication being presented on a given day between 1:00 and 2:00 p.m. The samples were coded with a randomized series of three numbers and presented to the panelists at random to equalize the sample sequence effect on food preference. The testing area was lighted with white fluorescent light. Panelists used sight and finger- and mouthfeel to evaluate appearance-kinesthetics characteristics. The panelists tested the dough with stew to determine overall acceptability. Samples were scored by using a 6-point hedonic scale (6 = like very much, 1 = dislike very much) (34). Sensory evaluation methods suggested by the Institute of Food Technologists were followed (29). The scoring sheet is given in Appendix A.

VII. MEASUREMENT OF AMINO ACID PROFILE OF CASSAVA AND SOYBEAN FLOURS

Two samples of cassava flour were submitted to a commercial laboratory (Woodson-Tenet Laboratories, 345 Adams St., Memphis, Tennessee) for a complete amino acid profile including tryptophan. Amino acid profile of soybean flour was provided by the manufacturer of the product as identified in Section I. Chemical scores were calculated for the essential amino acids of the proteins

in the cassava-soybean flour mixture. The FAO Provisional Pattern was used as the reference for calculating the chemical scores.

VIII. USE OF LABORATORY RATS TO DETERMINE GROWTH AND PROTEIN EFFICIENCY RATIO

Albino weanling male rats, Sprague-Dawley strain were used in the study. The rats were held individually in cages measuring 18 cm. wide x 24 cm. long x 18 cm. high with 1 cm. screening on the bottom and front. The cages were held in steel racks, six cages per row and five rows per side of each rack. The rats were divided into treatments by a procedure for randomization so that the weights of rats of individual treatments did not differ by more than 5 g. The weights of rats ranged from 40 g to 50 g, and the mean weight was 45 g.

IX. EXPERIMENTAL DESIGN FOR FEEDING STUDY

Ten rats (each considered a replication) were maintained for each treatment and the control. The procedure presented by the format in Table III was adequate to test the quality of protein for the different treatments. Temperature was maintained at 21° C to 24° C. Other environmental factors were controlled to provide favorable conditions for the animals.

TABLE III

EXPERIMENTAL DESIGN FOR FEEDING STUDY TO DETERMINE GROWTH RATE OF RATS AND PROTEIN EFFICIENCY RATIO

Listing	Protein[1] Containing Ingredients	Proportion of Ingredients, %	Estimated Protein Content, %	Actual Protein Content, %
1	C-S	100- 0	1.00	1.65
2	C-S	95- 5	3.00	3.60
3	C-S	90-10	5.00	5.57
4	C-S	85-15	8.00	8.61
5	C-S	80-20	10.00	10.56
6	Casein	100	10.00	10.34

[1]C = cassava flour; S = soybean flour.

X. DIET FORMULATION AND FEEDING STUDY

A control diet consisting of 10% protein supplied by casein was designed according to AOAC(5). Casein provided all the protein. Composition and the caloric content of the control diet are shown in Table IV.

In the experimental diets, cassava flour and cassava-soy flour mixtures were substituted completely for casein of the control diet.

Cottonseed oil and the salt mixture (footnote on Table IV) were added to provide diets with 8% fat and 5% salt, respectively. The vitamin content (footnote on Table IV) remained constant at 1%. Corn starch was added to the diet mixture to bring the total amount to 100 g. All diets provided approximately 419.0 Kcal per 100 g of feed. The proportional amounts of ingredients of the test diets are presented in Table V.

XI. EVALUATION OF THE FEEDING STUDY

Consumption of feed and body weight of rats were recorded every two days. At the end of 28 days the rats were sacrificed by use of carbon dioxide and incinerated. The PER value for protein of the casein and cassava-soy mixture containing 20% soybean flour, and rate of weight gain of rats were calculated.

TABLE IV

COMPOSITION AND APPROXIMATE CALORIC CONTENT OF THE CONTROL DIET FOR DETERMINING GROWTH RATE OF RATS AND PROTEIN EFFICIENCY RATIO

Ingredients	Amount, g	Approximate Kilocalories, (Kcal)
Casein	11.42	45.72
Cottonseed oil	8.00	72.00
Vitamin mixture[a]	1.00	0.00
Salt mixture[b]	5.00	0.00
Cellulose	1.00	0.00
Corn starch	73.58	294.32
	100.00	412.04

[a]Vitamin Diet Fortification Mixture contained the following vitamins expressed in mg/100 g except as indicated: Vitamin A (dry, stabilized), 2000 (IU); Vitamin D (dry stabilized), 200 (IU); Vitamin E (dry stabilized), 10 (IU), Menadione, 0.5; Choline, 200; p. Aminobenzoic acid, 10; Inositol, 10; Niacin, 4; Ca-D-pantothenate, 4; Riboflavin, 0.8; Thiamine HCl, 0.5; Pyridoxine HCl, 0.5; Folic acid, 0.2; Biotin, 0.04; and Vitamin B_{12}, 0.003.

[b]Salt Mixture: NaCl, 292.5 g; KH_2PO_4, 816.6 g; $MgSO_4 \cdot 2\ H_2O$, 9.35 g; $ZnCl_2$, 0.5452 g; $CuSO_4 \cdot 2\ H_2O$, 0.999 g; $CoCl_2 \cdot 6\ H_2O$, 0.476 g, $CaCO_3$, 800.8 g; $FeSO_4 \cdot 7\ H_2O$, 56.6 g; KI, 1.66 g; and $MnSO_4 \cdot 2\ H_2O$, 9.35 g.

Source of all ingredients: Nutritional Biochemical Corp., Cleveland, Ohio.

TABLE V

COMPOSITION OF EXPERIMENTAL DIET FOR DETERMINING GROWTH RATES OF RATS AND PROTEIN EFFICIENCY RATIO

Ingredients	Levels of cassava-soybean flours with protein content[1]				
	C-S 100- 0 (1.65%)	C-S 95- 5 (3.60%)	C-S 90-10 (5.57%)	C-S 85-15 (8.60%)	C-S 80-20 (10.56%)
Cassava flour	78.74	73.02	68.68	73.98	68.24
Soybean flour	0.00	3.85	7.68	13.12	16.97
Cottonseed oil	7.76	7.75	7.75	7.70	7.69
Salt mixture	3.35	3.19	3.00	2.47	2.33
Vitamin mixture	1.00	1.00	1.00	1.00	1.00
Cellulose	0.00	0.00	0.00	0.00	0.00
Corn starch	9.15	11.19	11.89	1.73	3.77

[1] C = cassava flour; S = soybean flour.

XII. STATISTICAL ANALYSIS

The Statistical Analysis System (SAS) computer program at the University of Tennessee Computer Center was used for computing the data (7). Data for texture, color, and panel evaluations were analyzed by analysis of variance as a factorial of a completely randomized block (5 x 3, level of soybean x replication) for color and texture, and (5 x 3 x 10, level of soybean x replication x panelists) for panel evaluation. Duncan's Multiple Range Test was used to determine significance among means (36).

CHAPTER IV

RESULTS AND DISCUSSION

I. PROXIMATE COMPOSITION OF CASSAVA AND SOYBEAN FLOURS

The proximate composition of the cassava flour is presented in Table VI. On the air-dried basis the percentage of crude protein was 2.09; ether extract, 0.31; crude fiber, 1.42; ash, 2.10; and nitrogen-free extract (NFE), 88.26. The cassava meal had a protein content of 2.38%. The flour and the meal contained 5.82% moisture. These values are in close agreement with the literature values (50). Non-protein nitrogen content of cassava meal was 21.36%.

Table VII presents the proximate composition of defatted soybean flour. On the air-dried weight basis the percentage of crude protein was 53.78; ether extract, 0.57; crude fiber, 1.24; ash, 7.30; and NFE, 33.11. The flour contained 3.37% moisture. These values agree with values published in the literature (28).

The protein contents of rat diets (Table V) containing 0%, 5%, 10%, 15% and 20% soybean flour were 1.65 $\pm$ 0.05%, 3.60 $\pm$ 0.13%, 5.57 $\pm$ 0.09%, 8.61 $\pm$ 0.15%, and 10.56 $\pm$ 0.08% respectively. The protein content of the diet containing casein (control) was 10.34 $\pm$ 0.07%.

The gross caloric energy content of cassava and soybean flours was 3,860 cal/g (1961 MJ) and 4,650 cal/g (187 MJ), respectively.

TABLE VI

PROXIMATE COMPOSITION OF THE CASSAVA FLOUR

Moisture,[1] %	Crude Protein,[2,3] %	Ether Extract,[1,3] %	Crude Fiber,[1,3] %	Ash,[1,3] %	Nitrogen-Free Extract,[4] %
5.82±0.11	2.09±0.04	0.31±0.09	1.42±0.14	2.10±0.03	88.26

[1] Mean of 6 observations with ± one standard deviation

[2] Mean of 10 observations with ± one standard deviation

[3] Values calculated on dry matter basis

[4] Calculated by difference: 100 minus mean % crude protein, minus mean % ether extract, minus mean % crude fiber, and minus mean % ash.

TABLE VII

PROXIMATE COMPOSITION OF DEFATTED SOYBEAN FLOUR

Moisture,[1] %	Crude Protein,[2,3] %	Ether Extract,[1,3] %	Crude Fiber,[1,3] %	Ash,[1,3] %	Nitrogen-Free Extract,[4] %
3.37±0.27	53.78±1.19	0.57±0.13	1.24±0.15	7.29±0.03	33.11

[1-4]See footnotes to Table VI.

Cassava flour had 5.58 mg of hydrocyanic acid (HCN)/ 100 g of the flour on an air-dried basis.

II. TEXTURE

The firmness of the cassava flour dough (control), consisting of 80 g of flour and 250 ml of water, as measured by the force required to extrude 100 g of the dough was 7.45 kg force. Higher amounts of water reduced the firmness values of the dough, whereas lower amounts of water increased the firmness values. Firmness decreased with increasing levels of soybean flour in the mixture. When the firmness values were plotted against the different volumes of water used to prepare the doughs of a particular treatment, there was a linear relationship (Table VIII).

Table VIII presents firmness values of doughs of cassava and cassava-soybean flours and the corresponding amounts of water used. Table IX presents the amounts of water required to produce doughs of the cassava-soybean flour mixtures with a consistency similar to that of the cassava dough (control).

The F-ratios for the analysis of variance for firmness values of doughs from different treatments are presented in Table X. After adjusting the amount of water required to prepare treatment doughs with a consistency similar to that of the cassava dough (control), the firmness values (Table XI) were not different at the 0.05 level. There was a difference between the replications at the 0.05 level, however.

TABLE VIII

EFFECT OF DIFFERENT AMOUNTS OF WATER ON FIRMNESS OF DOUGHS

Treatment[1]				
Cassava flour, %	Soybean flour, %	Water, ml	Firmness,[2] kg force	Correlation Coefficients
100 (Control)	0	200	12.50 ± 0.13	
		230	9.45 ± 0.04	- 0.998
		260	6.46 ± 0.03	
95	5	200	11.87 ± 0.11	
		230	8.93 ± 0.15	- 1.000
		260	5.99 ± 0.05	
90	10	200	11.29 ± 0.24	
		230	8.40 ± 0.04	- 0.999
		260	5.25 ± 0.04	
85	15	200	10.71 ± 0.50	
		230	7.88 ± 0.15	- 0.998
		260	4.46 ± 0.08	
80	20	200	10.19 ± 0.30	
		230	7.35 ± 0.20	- 0.997
		260	3.75 ± 0.15	

[1]In each treatment, the amount of water presented was added to 80 g of a mixture of cassava and soybean flours.

[2]Mean of 4 observations ± one standard deviation.

TABLE IX

FIRMNESS OF DOUGHS PREPARED FROM CASSAVA AND SOYBEAN FLOURS WITH ADJUSTED AMOUNTS OF WATER

Treatment[1]			
Cassava Flour,%	Soybean Flour,%	Water, ml	Firmness,[2] kg force
100	0	250.0	7.43±0.18
95	5	242.5	7.38±0.11
90	10	240.5	7.38±0.12
85	15	233.0	7.37±0.16
80	20	227.8	7.36±0.10

[1,2]See footnotes to Table VIII.

TABLE X

F-RATIOS FOR THE ANALYSIS OF VARIANCE OF THE EFFECT OF ADDED SOYBEAN FLOUR ON FIRMNESS OF CASSAVA-SOYBEAN FLOUR DOUGHS WITH ADJUSTED AMOUNT OF WATER

Source	D.F.	F-Ratio
Total	29	
Level of soybean flour	4	0.270^{NS}
Replications	2	4.550*
Residual error (mean squares)	23	0.015

*Significant at the 0.05 level.

^{NS}Not significant at the 0.05 level.

TABLE XI

F-RATIOS OF THE ANALYSIS OF VARIANCE FOR THE EFFECT OF ADDED SOYBEAN FLOUR ON THE HUNTER L, "a," AND "b" VALUES OF CASSAVA DOUGH

Source	D.F.	F-Ratio		
		L	"a"	"b"
Total	29			
Level of soybean flour	4	100.51**	40.62**	132.88**
Replication	2	1.52^{NS}	0.95^{NS}	8.09**
Residual error (mean squares)	23	0.23	0.01	0.07

**Significant at the 0.01 level.

^{NS}Not significant at the 0.05 level.

III. COLOR

The F-ratios for the analysis of variance for the effect of added soybean flour on the Hunter L, "a," and "b" color values of the cassava-soybean doughs are presented in Table XI. The Hunter values were affected (0.01 level) by the level of soybean flour in the cassava-soybean flour mixtures. Replication was significant (0.01 level) for Hunter "b" values.

The mean Hunter L values (Table XII) decreased when the percentage of soybean flour was increased in the dough. The cassava dough without soybean flour had an L value of 62.4. Thus, as the percentage of soybean flour was increased the resultant dough became darker. The mean L values for doughs containing 5 to 20% soybean flour were different (0.01 level) from each other. Visually, the dough containing 20% soybean flour was slightly darker than the cassava dough (control).

The red coloration of the doughs increased as the amount of soybean flour was increased (Table XII). For the dough without added soybean flour the "a" value was 0.47. The "a" value was increased to 1.02 when 20% soybean flour was incorporated into the flour. Although there were significant differences between the "a" values for most of the doughs, it is unlikely that the observer could ascertain differences in the degree of redness. Furthermore, the observer would not likely perceive a red coloration of the doughs.

The mean Hunter "b" values (Table XII) of the doughs of the various treatments were increased as the level of soybean flour was raised. Soybean flour increased the yellowness of the dough. The mean "b" values ranged from 16.88 for the cassava dough (0% soybean flour) to 20.22 for dough with 20% soybean flour. The yellow coloration of dough containing the higher levels of soybean flour were perceived as more yellow than doughs containing lower levels of soybean flour.

IV. SENSORY EVALUATION

F-ratios for the analysis of variance for the effect of added soybean flour to cassava flour on the appearance, texture, and eating quality are presented in Table XIII. The level of soybean flour in the mixture had an effect (0.01 level) on the three variables. Replication was not significant for any of the variables. The significant effect for the level of soybean flour caused changes in the appearance, texture, and eating quality such that the panel had preference among the treatments. Also, there was a difference (0.01 level) in the mean scores of the individual panel members.

Mean scores of individual panel members are presented in Table XIV for appearance, texture, and eating quality of the doughs having five levels of soybean flour. Mean panel scores for appearance, texture, and eating quality of dough prepared from cassava and soybean

TABLE XII

MEAN HUNTER L, "a," AND "b" VALUES OF DOUGHS PREPARED WITH CASSAVA AND CASSAVA-SOYBEAN FLOURS[1]

Treatment				
Cassava flour, %	Soybean flour, %	Hunter L	Hunter "a"	Hunter "b"
100	0	67.0 ± 0.9^{a}	0.47 ± 0.05^{a}	16.9 ± 0.2^{k}
95	5	66.3 ± 0.3^{a}	0.55 ± 0.10^{g}	18.1 ± 0.1^{j}
90	10	64.4 ± 0.4^{b}	0.65 ± 0.05^{f}	18.6 ± 0.2^{j}
85	15	63.3 ± 0.5^{c}	0.75 ± 0.05^{e}	19.3 ± 0.5^{i}
80	20	62.4 ± 0.2^{e}	1.02 ± 0.12^{d}	20.2 ± 0.5^{h}

[1]Mean of 6 observations with ± one standard deviation.

[a-k]Means within a column followed by the same letter are not different at the 0.01 level.

TABLE XIII

F-RATIOS FOR THE ANALYSIS OF VARIANCE OF THE EFFECT OF ADDED SOYBEAN FLOUR ON APPEARANCE, TEXTURE, AND EATING QUALITY OF CASSAVA DOUGH

Source	D.F.	Appearance	Texture	Eating Quality
Total	149			
Level of soybean flour	4	64.45**	209.79**	452.84**
Panelist	9	2.38^{NS}	1.49^{NS}	8.22**
Panelist level x level of soybean flour	36	1.43^{NS}	2.12^{NS}	3.16^{NS}
Panelist x replication	18	0.43^{NS}	1.23^{NS}	0.40^{NS}
Level of soybean flour and replication	8	1.32^{NS}	2.84^{NS}	3.29^{NS}
Replication	2	0.43^{NS}	0.72^{NS}	0.04^{NS}
Residual error (mean squares)	72	0.29	0.26	0.16

**Significant at the 0.01 level

^{NS}Not significant at the 0.05 level

TABLE XIV

MEAN SCORES OF INDIVIDUAL PANEL MEMBERS FOR APPEARANCE, TEXTURE, AND EATING QUALITY OF CASSAVA AND CASSAVA-SOYBEAN DOUGHS

Panelist code	Appearance[1,2]	Texture[1,2]	Eating Quality[1,2]
1	4.9[a]	4.1[b]	3.9[c,d]
2	4.9[a]	4.5[b]	4.4[c]
3	5.0[a]	4.4[b]	3.5[d]
4	5.2[a]	4.0[b]	3.7[c,d]
5	4.8[a]	4.4[b]	4.2[c,d]
6	5.3[a]	4.3[b]	3.9[c,d]
7	4.9[a]	4.3[b]	3.6[c,d]
8	4.8[a]	4.0[b]	4.1[c,d]
9	4.8[a]	4.3[b]	3.6[c,d]
10	5.2[a]	4.1[b]	3.7[c,d]

[1]Hedonic scale: 1 = dislike much much; 2 = dislike moderately; 3 = dislike slightly; 4 = like slightly; 5 = like moderately; 6 = like very much.

[2]Mean of three observations.

[a,b]Means within a column followed by the same letter are not different at the 0.05 level.

[c,d]Means followed by the same letter are not different at the 0.01 level.

flours are presented in Table XV. The samples of doughs with 5-15% soybean flour were scored at 5 or above for appearance, indicating that the panel considered appearance above like moderately. At the 20% level of soybean flour, the samples were given a mean score of 3.6 (below like slightly). At this level, the yellow color imparted by soybean flour rendered the appearance of the dough unacceptable.

Increasing the levels of soybean flour improved the texture of the dough from below dislike slightly (score = 2.6) to above like moderately (score = 5.5). The doughs prepared with 10, 15, and 20% soybean flour were preferred for their texture over the doughs with 0 or 5% soybean flour. The doughs containing 20% soybean flour was scored highest at 5.5.

Eating quality of the cassava dough was improved progressively by adding soybean flour up to 15%. At 20% soybean flour, the dough was unacceptable, receiving a mean score of 1.5 (below dislike moderately). At the highest level of soybean flour, the dough lost all the properties of cassava and tasted similar to that of a dough prepared from soybean flour.

The data for panel evaluation of the different doughs are presented in Appendix B. The mean scores of the individual panel members were not different from each other for appearance and texture but were different for

TABLE XV

MEAN PANEL SCORES FOR APPEARANCE, TEXTURE, AND EATING QUALITY OF CASSAVA DOUGH WITH SOYBEAN FLOUR ADDED TO CASSAVA FLOUR

Treatment				
Cassava flour, %	Soybean flour, %	Appearance	Texture	Eating Quality
100	0	4.9 ± 0.6^{a}	2.6 ± 0.4^{d}	3.6 ± 0.5^{g}
95	5	5.0 ± 0.4^{a}	3.1 ± 0.4^{d}	$3.9\pm0.5^{f,g}$
90	10	5.5 ± 0.3^{a}	4.7 ± 0.6^{c}	4.8 ± 0.4^{f}
85	15	5.7 ± 0.3^{a}	5.4 ± 0.4^{c}	5.6 ± 0.4^{e}
80	20	3.6 ± 0.3^{b}	5.5 ± 0.2^{c}	1.5 ± 0.5^{h}

[1]Scoring system in footnote on Table XIV.

[2]Mean of 30 observations with ± one standard deviation.

[a-c]Means followed by the same letters within a column are not different at the 0.05 level.

[e-h]Means followed by the same letter are not different at the 0.01 level.

eating quality. The mean scores for eating quality of two panelists were different from each other, but these two mean scores were not different from the mean scores of the other panelists.

V. AMINO ACID COMPOSITION AND CHEMICAL SCORES OF CASSAVA AND SOYBEAN FLOURS AND THEIR MIXTURES

The amino acid composition of proteins is a very important parameter of protein quality. The composition and quality of cassava protein are affected by processing. The complete amino acid profiles of cassava and soybean proteins used in this study are presented in Table XVI. Also, this table presents the compostion of amino acids of the Food and Agriculture Organization, United Nations (FAO) Provisional Pattern.

The content of amino acids in the cassava protein was very low. Although literature values for sieved cassava flour were not available for comparison, values reported in the literature for cassava meal are higher than values of the experimental cassava (22).

The essential amino acid content of the proteins of soybean flour is slightly higher than those reported in the literature. The difference between the literature and the experimental values may be due to varietal differences of the soybeans. The level of individual

TABLE XVI

AMINO ACID COMPOSITION OF CASSAVA FLOUR AND DEFATTED SOYBEAN FLOUR

Amino acid	Cassava[a] flour	Soybean[b] flour	FAO Provisional[c] Pattern (1973)
	g/16 g Nitrogen		
Essential			
Lysine	0.33	8.44	5.5
Methionine + 1/2 Cystine	0.23	3.20	3.5
Tryptophan	<0.01	2.05	1.0
Threonine	0.15	5.45	4.0
Isoleucine	0.13	6.42	4.0
Leucine	0.26	10.64	7.0
Phenylalanine + Tyrosine	0.38	11.76	6.0
Valine	0.35	6.48	5.0
Non-essential			
Arginine	0.63	9.74	
Histidine	0.22	3.55	
Serine	0.85	6.88	
Glutamic acid	1.06	26.91	
Glycine	0.19	6.12	
Aspartic acid	0.36	16.24	
Alaline	0.29	6.09	
Proline	0.15	6.80	

[a]Mean of two determinations.

[b]Data supplied by A. E. Staley Manufacturing Co., Decatur, Ill.

[c]Reference 25.

amino acids of the experimental soybean flour protein is higher than that of the FAO Provisional Pattern, except for the sulfur-containing amino acids, methionine and cystine. The total sulfur-containing amino acid level (3.2 g/16 g N) was the same as that reported, but slightly lower than the FAO Provisional Pattern value (3.5 g/16 g/N). The lysine content (8.44 g/16 g N) in the experimental soybean flour was higher than the value (6.9 g/16 g N) reported in the literature (45,46).

Tryptophan was the most deficient in that its content was less than 0.01 g/16 g N. The sulfur-containing amino acids were also very low (0.23 g/16 g N). Cystine was not detected, therefore, methionine was the only sulfur amino acid present. Comparing the essential amino acids in cassava flour protein with those of FAO Provisional Pattern, cassava was deficient in all of the amino acids.

Tables XVII and XVIII list, respectively, the essential amino acid composition and their chemical scores for protein in the mixtures of cassava and soybean flours. The mixtures with up to 20% of soybean flour were deficient in all the amino acids as indicated by the chemical scores in Table XVIII.

TABLE XVII

ESSENTIAL AMINO ACIDS IN MIXTURES OF CASSAVA AND SOYBEAN FLOUR

Essential Amino Acid	Ingredients[1] C 100%	S 100%	Mixtures of ingredients[2] C-S 95-5	C-S 90-10	C-S 85-15	C-S 80-20
			g/16 g Nitrogen			
Lysine	0.33	8.44	0.73	1.14	1.55	1.95
Methionine + ½ Cystine	0.23	3.20	0.38	0.53	0.68	0.82
Tryptophan	0.01	2.05	0.11	0.21	0.32	0.42
Threonine	0.15	5.45	0.41	0.69	0.95	1.21
Isoleucine	0.13	6.42	0.44	0.76	1.07	1.24
Leucine	0.26	10.64	0.78	1.30	1.82	2.34
Phenylalanine + Tyrosine	0.38	11.76	0.95	1.52	2.08	2.65
Valine	0.35	6.98	0.68	1.02	1.33	1.68

[1,2]C = cassava flour; S = soybean flour.

TABLE XVIII

CHEMICAL SOURCES FOR ESSENTIAL AMINO ACIDS OF CASSAVA FLOUR, SOYBEAN FLOUR, AND THEIR MIXTURES WITH FAO PROVISIONAL PATTERN AS THE REFERENCE[1]

Essential Amino Acid	Ingredients[2]		Mixtures of Ingredients[2]			
	C 100%	S 100%	C-S 95-5%	C-S 90-10%	C-S 85-15%	C-S 80-20%
Lysine	6	153	13	21	28	35
Methionine + 1/2 Cystine	7	91	10	15	19	25
Tryptophan	1	205	11	21	32	42
Threonine	4	136	10	17	24	30
Isoleucine	3	161	11	19	27	34
Leucine	4	152	11	19	26	33
Phenylalanine/ Tyrosine	6	196	16	25	35	44
Valine	7	140	14	20	27	34

[1]Values expressed as percentage of the ratio of amino acid in the FAO Provisional Pattern.

[2]C = cassava flour; S = soybean flour.

VI. PROTEIN EFFICIENCY RATIO (PER) OF CASSAVA-SOYBEAN FLOUR MIXTURE AND EFFECT OF INCREASING LEVELS OF SOYBEAN FLOUR ON THE WEIGHT GAIN OF RATS

Table XIX presents the gain in weight by the rats over the 28-day period. The corresponding amount of food eaten during that period is given in Appendix C. The PER of cassava-soybean mixture containing 20% soybean flour was 1.55 on the basis of PER of casein = 2.5. The unadjusted casein PER value was 2.91. The experimental value is 62.8% of that of casein.

Increasing the proportion of soybean flour in the diets caused a corresponding increase in the weight gain of the rats. At 0 and 5% soybean flour the rats began to lose weight very soon after they began to consume the experimental diets. The rate of weight loss was greater for rats consuming the diet with 0% soybean flour. At 10% soybean flour, the weight gain of rats was almost constant over the period of feeding. At 15% soybean flour the rats gained an average of 1.07 g/day.

Compared to casein with an average gain of 4.12 g/day, the rate of weight gain of rats fed all experimental diets was lower. However, the diet with 15% soybean flour should be singled out for further discussion. At this level the cassava soybean flour mixture supported weight gain of the rats. Also, level of soybean flour in the dough was generally most acceptable to the panel (Table XV and Appendix B). The dough containing 20% soybean flour was

TABLE XIX

EFFECT OF INCREASING LEVELS OF SOYBEAN FLOUR IN CASSAVA-SOYBEAN FLOUR MIXTURE ON THE WEIGHT GAIN OF RATS[1]

	Level of cassava-soybean flour[2] with protein content					
	C-S 100-0 (1.65%)	C-S 95-5 (3.60%)	C-S 90-10 (5.57%)	C-S 85-15 (8.60%)	C-S 80-20 (10.56%)	Casein diet (10.34)
Day	Weight gain, g					
0	63.7	58.0	58.7	61.8	62.1	66.0
2	58.5	54.2	56.4	60.8	64.7	70.7
4	56.3	54.0	57.0	65.0	73.5	87.0
6	56.3	54.0	57.0	65.0	73.5	87.0
8	53.0	52.1	54.1	64.8	73.5	91.4
10	52.8	51.3	55.4	66.4	77.9	99.6
12	50.6	50.2	55.4	68.9	82.0	111.2
14	50.6	49.1	54.2	70.5	86.4	119.1
16	47.8	49.0	55.0	73.3	91.6	130.7
18	45.8	47.3	54.1	75.0	95.5	135.4
20	45.2	47.3	54.9	77.7	98.6	143.2
22	44.5	48.4	57.0	83.2	106.6	159.8
24	44.5	47.6	56.4	85.8	114.0	166.2
26	43.5	46.2	55.0	88.5	118.2	176.8
28	43.3	47.7	57.0	91.0	122.4	181.5

[1]Mean weight gain of 10 rats.

[2]C = cassava flour; S = soybean flour.

unacceptable for appearance and eating quality due to a yellow color and undesirable taste contributed by the soybean flour. The texture of this dough was as acceptable as that of the dough with 15% soybean flour.

CHAPTER V

SUMMARY

Soybean flour with 53.78% protein was mixed with cassava flour containing 2.09% protein. The flours were analyzed for moisture, protein, crude fat, crude fiber, ash, NFE (by difference), gross caloric, energy and amino acid content. Cassava flour was analyzed for residual hydrocyanic acid (HCN).

Five mixtures of cassava-soybean flour were prepared. The mixtures contained 0, 5, 10, 15 and 20% soybean flour. The mixtures were analyzed for texture, color, and organoleptic attributes (appearance, texture, and eating quality). The chemical scores were calculated for the essential amino acids of cassava and soybean proteins and the mixtures. Cassava and cassava-soybean flour mixtures were used to prepare diets for feeding to rats to determine protein efficiency ratio (PER) and the rate of weight gain of rats.

Dough samples prepared from mixtures of cassava and soybean flours were softer and less gummy than samples prepared from cassava flour alone (control). By reducing the amount of water used to prepare doughs containing soybean flour, firmness was increased. After adjusting the amount of water used to prepare doughs containing each level of soybean flour, doughs of all the mixtures exhibited

textural values similar to that of the control dough.

Samples containing soybean flour were darker, more red, and more yellow than the control sample.

The panel indicated a preference for dough containing 15% soybean flour. On a six-point hedonic scale, cassava dough was scored 4.93 (like moderately) for appearance, 2.60 (between dislike moderately and dislike slightly) for texture, and 3.63 (between dislike slightly and like slightly) for eating quality. The 15% level of soybean flour was scored above like moderately for the three variables. Considering appearance, texture and eating quality together indicated a compromise at 15% soybean flour level as being the most liked dough.

The protein of cassava was deficient in all amino acids. Cystine was not detected upon analysis and the tryptophan content was less than 0.1 g/16 g N. When compared to the FAO Provisional Pattern for essential amino acids, the sulfur-containing amino acids were limiting in soybean flour. In cassava flour all the amino acids were limiting. Mixtures of all cassava and soybean flours were deficient in all the amino acids also.

Protein efficiency ratio of the cassava-soybean flour mixture containing 10.56% protein was 1.55 when compared to the PER of casein (PER = 2.5 adjusted). Rats fed cassava containing 0% and 5% soybean flour lost weight

during the experimental period. At 15% soybean flour level, the rats gained weight consistently indicating that the flour mixture can support weight gain of the rats.

The flour mixture containing 15% soybean flour had 9.85% protein and 3,966 cal/g of flour. Also, the mixture contained 5.32 mg HCN/100 g of flour. At this level of the acid, a human adult male weighing 50 kg will have to eat about 500 g of the flour mixture to reach the lethal dose of 50-60 mg of hydrocyanic acid.

The findings of this study suggest that cassava may be fortified with defatted soybean flour up to 15% without adversely affecting acceptability of the dough. Appearance and eating quality of the dough are improved.

At this level of soybean flour, the energy requirements of a "reference" man and a "reference" woman are met.

Since all the amino acids in the mixture containing 15% soybean flour are limiting, the product cannot meet the amino acid requirements of the people. However, these comments are given assuming that no other sources of protein such as legumes and animal products may be eaten with the cassava-soybean flour product. The above combination taken as a whole will meet the protein needs of the people.

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APPENDIX

APPENDIX A

SCORE SHEET USED FOR SENSORY EVALUATION

Name_____ Data _____

You will be given five products, one at a time, made from cassava flour. For each product perform the following observations using the scale designed for each attribute. For each coded sample check at the point that best describes your feeling about the product. Feel free to make any comments about the products.

(a) Check the appearance of the product to determine whether it is acceptable to you.

Code number	_____	_____	_____	_____	_____
Like very much	_____	_____	_____	_____	_____
Like moderately	_____	_____	_____	_____	_____
Like slightly	_____	_____	_____	_____	_____
Dislike slightly	_____	_____	_____	_____	_____
Dislike moderately	_____	_____	_____	_____	_____
Dislike very much	_____	_____	_____	_____	_____

Comments:_____
_____

(b) To test for texture (degree of gumminess) compress a portion of the product between your fingers. Then place it on your tongue and move your mouth up and down. Indicate your feeling about the product.

Code Number	_____	_____	_____	_____	_____
Like very much	_____	_____	_____	_____	_____
Like moderately	_____	_____	_____	_____	_____
Like slightly	_____	_____	_____	_____	_____
Dislike slightly	_____	_____	_____	_____	_____
Dislike moderately	_____	_____	_____	_____	_____
Dislike very much	_____	_____	_____	_____	_____

Comments:_____
_____

(c) You will be given five products, one at a time, made from cassava flour. Take the sample, dip it in the stew and eat it. After you make your judgment, check at the point that best describes your feeling about the product.

Code number	_____	_____	_____	_____	_____
Like very much	_____	_____	_____	_____	_____
Like moderately	_____	_____	_____	_____	_____
Like slightly	_____	_____	_____	_____	_____
Dislike slightly	_____	_____	_____	_____	_____
Dislike moderately	_____	_____	_____	_____	_____
Dislike very much	_____	_____	_____	_____	_____

Comments: _____

_____

APPENDIX B

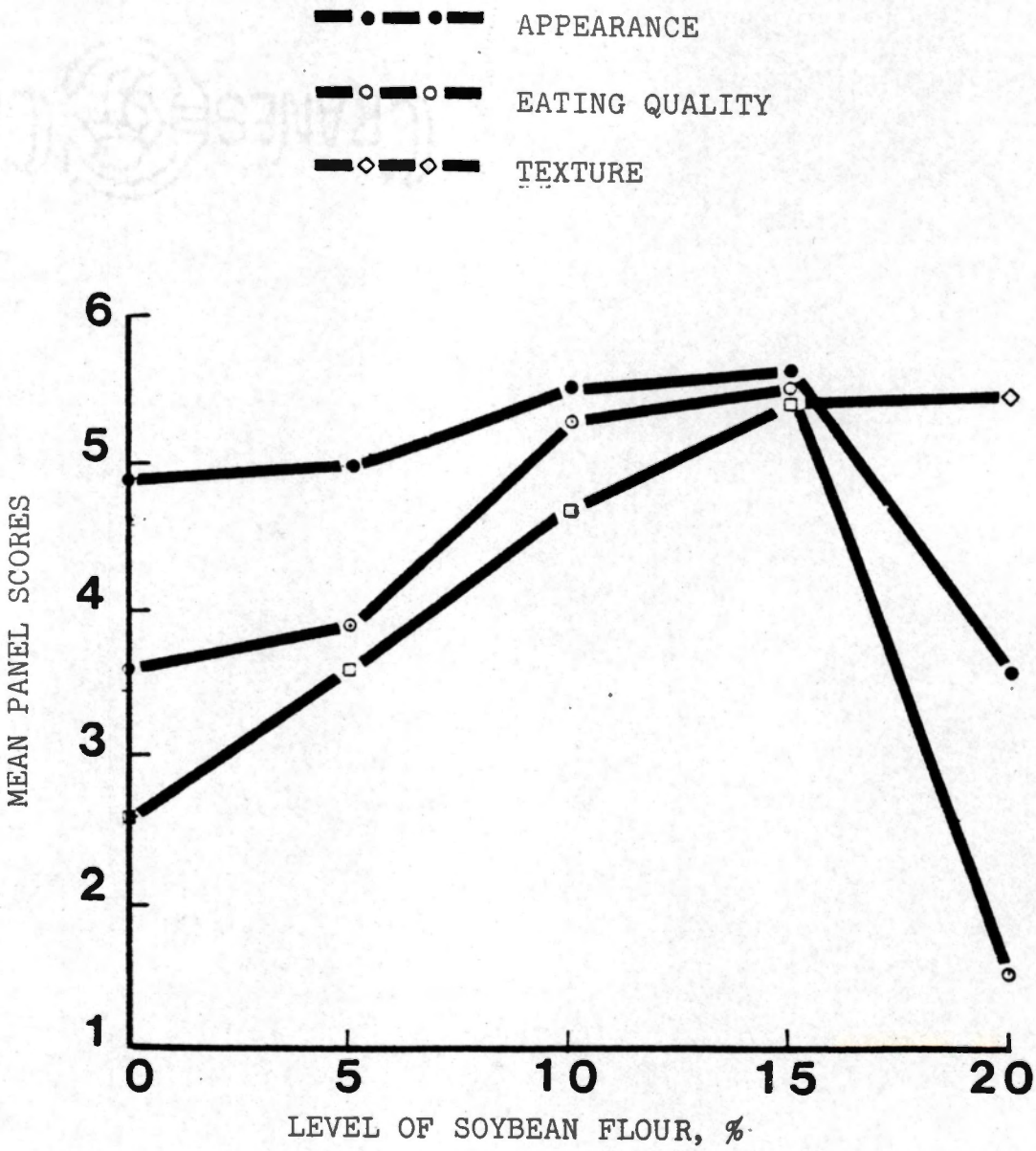


Figure B-1. Mean Panel Scores Plotted Against Level of Soybean Flour for Appearance, Texture, and Eating Quality.

APPENDIX C

TABLE C-1

WEIGHT OF FOOD EATEN BY RATS OVER THE 28-DAY PERIOD

Day	Level of cassava-soybean flour[2] with protein content					Casein Diet (10.34%)
	C-S 100-0 (1.65%)	C-S 95-5 (3.60%)	C-S 90-10 (5.57%)	C-S 85-15 (8.60%)	C-S 80-20 (10.56%)	
	Weight of food eaten,[1] g.					
0	0.0	0.0	0.0	0.0	0.0	0.0
2	9.7	9.6	10.4	11.2	12.6	18.1
4	11.3	15.3	13.7	16.8	19.6	22.0
6	13.7	15.3	15.7	17.8	22.2	13.7
8	11.3	14.1	13.7	15.9	18.9	24.6
10	9.9	11.1	13.4	15.3	18.2	24.5
12	9.7	11.0	18.7	15.8	22.5	28.2
14	10.7	11.3	13.1	16.1	28.1	31.6
16	10.7	11.3	13.1	16.1	23.1	31.6
18	10.4	10.8	13.5	17.9	23.7	30.4
20	11.5	10.8	14.2	17.4	22.7	31.1
22	9.3	10.3	12.5	17.4	23.4	31.6
24	11.2	11.4	16.1	20.2	28.1	39.6
26	8.0	10.1	11.6	20.1	23.9	38.1
28	9.2	11.4	12.6	21.0	27.2	39.4

[a]Mean of 10 observations.

[b]C = cassava flour; S = soybean flour.

VITA

Claver R. Temalilwa was born in January, 1947, in Bukoba, Tanzania, East Africa. He attended primary and junior secondary education in Bukoba, and high school in Shinyanga, Tanzania. In March, 1973 he graduated from the University of Dar-es-Salaam, Tanzania, with a Bachelor of Science degree in Chemistry, Botany and Education. He taught Chemistry in high school for two years, and in 1975 he joined Tanzania Food and Nutrition Center as a food chemist. After working for two and one-half years in that capacity he was awarded a scholarship by the center to study Food Technology and Science at the University of Tennessee, Knoxville. Since June, 1978 he has been working to complete the requirements for the degree of Master of Science. He is a member of the Institute of Food Technologists (USA). He is married and has two children.