HIGH-PROTEIN BREADS FROM WHEAT FLOUR FORTIFIED WITH PEANUT FLOUR AND PEANUT-SOY BLENDS AND THEIR NUTRITIVE VALUES

by

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A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

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KANSAS STATE UNIVERSITY

Manhattan, Kansas

1975

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INTRODUCTION

Peanuts are produced in many countries; China, India, Nigeria, Sengal and the U.S.A. are major producers (71). Oil, ofcourse, is the major product of peanuts. Peanut meal or flour, however, has been reported to blend with cereals, pulses, and other products to produce high-protein foods. Nutritionally peanut protein is inferior to cotton seeds and soy proteins, but it is readily available for protein supplementation in countries like India and Nigeria (112, 33).

An adequate food supply is one of the paramount problems facing the steadily increasing world population. Of all the major food components, protein is the most expensive. The less expensive source of protein including cereals, is poor in nutritional quality. Since cereals make up the largest part of the diets for undernourished people over the world, it seems worthwhile to improve the quality of proteins (111).

Protein quality of foods can be improved by supplementation either with additional source of protein or with essential amino acids. According to Rosenberg (90), the most desirable procedure is often an appropriate combination of those two methods. For many people in the world, both quantity and quality of protein in the daily diet are inadequate. This deficiency can be corrected by supplementation with high protein materials to produce foods with better amino acid balance and higher protein content. (29).

Cereals, which are the major source of both calories and protein in the world diet, particularly in the developing countries. All cereals are deficient in the amino acid, lysine (107). Bread has been considered a staple food throughout world (92). Modern interest in the nutritional improvement of bread now centers principally in its contribution of proteins (98). High consumption, acceptability and low price make bread an ideal vehicle for protein supplementation (81).

Available information concerning utilization research on peanut flour or meal as human food is scarce. Robinson (86), studied the effect of supplementary peanut flour on rheological properties and baking performances of America and Indian-Pakistani breads. Lorenz and Maga (56), reported that reduced atmospheric pressures could improve the baking quality of wheat flour fortified with various protein-rich additives including peanut flour. Loaf volume and grain score of their fortified breads, however, required further improvements to make the breads acceptable.

Oil seed flours changes the properties of absorption, mixing tolerance and other physical properties of dough, loaf volume and texture may be affected. This can be improved by the addition of dough conditioners; they might function as solid fat in increasing breads volume. Furthermore, the stearoyl group in SSL, might be sufficient to replace shortening (57, 69, 101). Soy fortified bread with SSL, has been improved the loaf volume, and texture. By the addition of SSL to peanut fortified breads, can be improved the physical properties of dough, loaf volume and texture.

Peanut protein is deficient in metheonine, lysine, isoleucine and threonine. Soy protein contains more lysine, threonine, leucine, isoleucine, and valine than peanut protein, so adding soy flour to peanut flour, should improve the protein quality (amino acid pattern) of peanut fortified bread. The combination of peanut-soy flours fortified breads, should improve the protein quality.

The present work was conducted to evaluate how to improve the processing and quality of the high protein breads prepared from wheat flour fortified with peanut or soy or a blend of peanut-soy flours, by adding a dough conditioners and also to evaluate the nutritive value of such breads.

REVIEW OF LITERATURE

Improvement of nutritional status of the world population with introduction of new high protein foods is time consuming and difficult due to food habits. The ability of soy flour to fortify white bread has been shown by several workers, but its use often resulted in disappointment because of poor color, flavor and loss in loaf volume (65, 69). Soy flour increases absorption and hence, produces greater dough yield than do the other common protein additives, impair excellent handling and machining properties to the dough, and shows nutritional equality or superiority to the other available protein additives (104).

Ofelt et al. (69), found that with the proper amount of oxidation the use of soy flour up to 5% did not significantly impair loaf volume, crumb character, or dough handling properties. Nitrogen solubilities of defated soy flours were in the range of 50 to 60% and the bromate requirements, 3.0 to 4.0 mg% based on the weight of the wheat flours where 5% soy flour was used. An increase in dough absorption of 1% for each 1% of soy flour was found desirable. In baking tests, higher levels of soy flour decreased loaf volume, heated soy flour was still more injurious in proportion to their degree of heat treatment. Heat treatment raised the water absorption of the soy flours in doughs (78).

The fortification of wheat flours with soy flour could be done upto 10% level with out affecting consumer acceptability, but slightly modifying the procedure of making bread. The optimum fermentation time with 10% soy fortification was found to be 100 minutes (91).

Matthews et al. (60) investigated that the effects of adding oil seed flours such as cotton seeds, peanuts, safflower seeds and soy on doughs and breads. Data on the farinograph, extensigraph, amylograph and various histological staining techniques were used as indices of performance of oil seed flours with wheat flour. Oil seed flours increased absorption and usually decreased mixing tolerance of doughs concomitantly with increases in replacement level of wheat flour.

Excellent breads could be made with blends containing up to 8% soy flour, the quality of the bread as measured by loaf volume and crumb grain was better than wheat bread provided the quantity of potassium bromate used in the baking formula was increased according to the amount of soy flour used (27).

Soy flour proteins do not, however contribute to the unique viscoelastic bread making properties of wheat gluten. Adding soy flour may necessitate changes in bread making procedures, such as fermentation schedules of water absorption, or the addition of certain ingredients, like oxidants, to counteract the effects of reducing components of soy flour (80).

However at higher replacement levels of oil seed fours on wheat flours, loaf volume was severely decreased along with serious deterioration of crumb color, grain and texture. The maximum level of replacement depends on the type of non wheat flour, the strength of the wheat flour, the baking procedures and the dough stabilizing compounds used. The dough conditioners increases loaf volume, and the organoleptic properties of the soy bread comparable to bread with 100% wheat flour (87).

BAKING PERFORMANCES

Tsen *et al.* (100) found a simple method for making high protein breads would be valuable for expanding use of high protein breads to improve man's diet around the earth. In this study undertaken to evaluate various processing conditions (with special attention fermentation), to shorten the bread making process (K. State process).

A study was made of 70% sponge dough, straight dough, and 100% sponge dough procedures to produce 12% soy fortified bread. Proper dough mixing and absorption, and use of SSL were found to be the most important factors in producing high quality soy fortified breads. The most critical factors in producing high-quality 12% soy fortified bread were shown to be dough mixing, absorption, and the use of the dough conditioners, SSL, studies conducted that 12% soy-fortified flours requires a 5% increase in water over that expected for a dough composed of only wheat flour, and as much as a 40% reduction in mixing time (59).

Cotton (17) reported that in bread production with low levels of soy flour, upto 3%, did not expect any appreciable change in absorption, mix and oxidant compared with NFDM. As higher levels of soy flour, more bromate can be beneficiable, 10 ppm increase for 5% soy and 30 ppm increase for 12% soy, SSL or ethoxylated mono glyceride (EM) have more beneficial effect than oxidants. Soy flour took a 3/4 lb extra water for each one pound added to formula. At a level of 12% soy flour, bread dough required about one third less mixing. These adjustments were made to optimize bread volume, grain and texture.

Rooney *et al.* (87) studied the baking properties of various oil seed flours as replacements for 25% of wheat flour. The breads had low loaf volume and functional properties of the oil seeds varied. Heat treated peanut flour produced bread with significantly better loaf volume than peanut flour from raw peanuts. Heat treatment and chemical modification of soy flour influences baking properties. It is reasonable to assume that processing conditions influence the functional bread-making properties of other oil seed products.

Robinson (86), studied the effect of supplementary peanut flour on rheological properties and baking performance of American and Indian-Pakistani breads. Lorenz and Mage (56) reported that reduced atmospheric pressures could improve the baking quality of wheat flour fortified with peanut flour.

EFFECTS OF SURFACTANTS

Dubois and Ash (21) studied various types of dough conditioners for use in yeast raised bakery products. The novel use of dough conditioner, SSL, CSL, and EM to produce acceptable high protein breads. Different factors and processing conditions were evaluated using upto 16% soy flour. By adding SSL, CSL or EM, high levels of various protein-rich food stuffs can be used to enhance the nutritional value of finished bread. CSL, SSL and EM could improve the baking performance of wheat flour fortified with soy flour or other protein rich food stuffs, SSL was more effective than, CSL. The significance of the findings were enhanced by the fact that SSL and CSL were already being used commercially in the baking industry. Fortification of soy flour for bread, could adversely affect both rheological properties and baking qualities of wheat flour. SSL, could increase the stability of dough containing 12 to 28% soy flour. The effect was enhanced with increased additions of SSL (0.25-2%). EM also gave a larger loaf volume but a lower grain score than SSL. Baking quality of defatted soy flour was inferior to that of full-fat soy flour, even compared on an equalent basis (99, 102, 101, 103).

The use of soy flour as an additive in baking industry. It is used mainly in products which contains yeast, especially bread. Soy flour contains a number of enzymes (13). The enzyme lipoxidase which has a bleaching action on wheat flour and gives improvement in flavor and color of breads. During baking, the enzyme activity was destroyed and undesirable flavor components of the soy flour were lost so that the finished baked products has an acceptable flavor. If this soy flour was used at higher levels, there would be a soy flavor imparted to the bread (51).

The use of SSL in yeast-leavened baked products did not require great changes in procedures and formulations. SSL imparts strength to the dough giving it tolerance to withstand production and ingredient variations. Optimum usage levels generally fall in the range of 0.5 to 1.0% of the flour weight (97).

Lorenz _et al_. (55) had showed that the oil seed flours were in high in protein, low in sodium, and contribute to flavor and taste when used in baked products. These flours could greatly improve the taste of low-sodium breads without increasing the flavor of low-sodium bread containing greater than 10 mg Na/100 g. bread and the possibility of using medium chain triglycerides (MCT) as a shortening replacement in special dieting bread was investigated. Supplementation with oil seed flours further decreased total scores, but flavor acceptability was increased, bread baked with MCT had considerably lower specific loaf volume, and total score than bread baked with lard or vegetable shortening. Grain was more open and texture slightly harsh though no differences in flavor were noted.

STALING PROPERTIES

The mechanism by which surfactants inhibits staling is not yet fully understand. The Bloom Gelometer measures the weight in grams required to cause a circular plunger, 1 inch in diameter, to depress the surface of a 1 inch thickness of bread by 4 mm. The firmer the crumb is the greater the weight is required to depress the surface 4 mm. When making compressibility tests the end slices of the loaf were not used. During the staling of bread, the crust becomes soft and leathery; the crumb becomes firm, harsh, and crumbly to the touch, and the bread loses moisture (23).

Bohn (10) showed that bread made with soy flour was more compressible and its rate of staling was slower than that of the bread produced under similar conditions from wheat flour alone, it was clearly recognized that not only the physical properties of the crumb were involved, but also development of undesirable flavor and odor. Present knowledge indicates that changes in firmness of the crumb may result from loss of water from gluten to starch as the latter aggregates. There was some evidence that movement of moisture from crumb to crust may also be involved. The browning (Maillard) reaction was probably the chief cause of undesirable flavors and odors that develop during staling (58).

Finny *et al*. (28) showed that the quality of the soy bread measured by crumb, grain and loaf volume being equal to that of wheat bread, provided the quantity of potassium bromate used in the baking formula was increased. Crumb color for bread containing soy flour were creamy gray, the degree of which dependent on the kind and amount of soy flour used.

Zobel (114) studied that the bread crust color was due to the Maillard reaction and not to carmelization of sugars and dextrins as formerly believed (3).

NUTRITIONAL VALUE

Wheat flour and bread.

The study of the nutritional value of new sources of combination of proteins attracts more and more interest in the world. This is especially true in under developed countries where the problems of protein malnutrition is acute (18).

The primary function of dietary proteins is to furnish a mixture of amino acids in a pattern appropriate for the synthesis of tissue proteins and other nitrogenous substances essential to the organism (2). Apart from physiological variations in the total quantity of protein needed, present knowledge suggests that the best dietary protein or combination of proteins will be those in which there is a proper balance among the amino acids to meet over-all needs for growth, lactation, pregancy and tissue repair (31).

From studies with animals much is known about the relation between protein and growth quantity and quality of protein in the diet has been found to affect growth since the classic experiments of Osborne and Mendel. They showed that rats grow at satisfactory rates when 15% or more of casein was provided in the diet, but at subnormal rates when the casein level was 12% or less (73).

The beneficial role that amino acid supplementation can play in improving the protein quality of cereal grains. Lysine is the only amino acid involved in cereal improvement available in commercial quantities. The lysine can be added either in the form of a protein such as milk, fish or soy or as the lysine hydrochloride. The net value of dietary protein, however, is based not only on protein quality but also on the quantity of protein consumed (50).

In many instances supplementation with the first limiting amino acid to the reference level will accumulate the deficiency of the second limiting amino acid in the protein. The amount of the most limiting amino acid to add to a deficient protein for maximal response in nutritive value should just balance the second most limiting amino acid (11). Harris et al. (36) and Gillespie et al. (34) studied lysine deficiency in young rats. The man's symptoms of lysine deficiency included stunting growth, muscle wasting, hypoproteimia, and reduction of calcification of the bones.

Supplementing bread with protein in combination with amino acids has several advantages. The protein supplements raises the protein level and generally supplies enough of the second limiting amino acid so that a better response of the second limiting amino acid (generally lysine) can be obtained. At the same time adding lysine enables one to attain a nutritionally improved bread at a level of protein supplementation less likely to impair functional properties of the dough or consumer acceptance of the bread (79).

The significance of the use of fortified flour has been tested by feeding rats. The reproduction and lactation performances was better among the rats receiving enriched flour, since a greater number of young were born and a greater number weaned by the females on the diets containing enriched flour (108). Deshpande et al. (19), showed that the rate of growth of rat was increased from 3 to 21 gm/week when their diet, containing 78% of white flour was supplemented with 0.5% of L. lysine and 0.4% of D.L. threonine. Further improvement in growth was obtained when 7 more essential amino acids were added.

Rosenberg et al. (88), investigated the effect on the growth of rats, of adding lysine, therefore, valine and methionine to a diet in which the protein was derived from white bread which contained 3% non-fat milk solids. From their results they concluded that the only amino acid which was deficient in their commercial white bread was lysine since no further improvement in growth was obtained by supplementing the diet with other amino acids.

Hutchinson et al. (46) showed that the protein of whole meal bread promoted a better rate of growth of young rats than that of white bread. They used breads that did not contain any milk solids. They attributed this effect to the lower lysine content of white bread. When white bread was supplemented with lysine, it was no longer inferior to the whole meal bread, in promoting growth in rats. The extreme sensitivity of the weaning rat to small changes in the lysine content of diets in which the protein was provided by wheat flour.

The recognized protein inadequacy of wheat flour is, therefore not the result of the lack of total protein per calorie, but is due to the low biological value of wheat protein (44). Rice et al. (85) as shown that, when a diet based on white flour was supplemented with lysine, can result in an increased nitrogen retention.

Peng et al. (77), showed that animals fed a low protein diet have their food intake limited by an excess energy intake in relation to protein. The decrease in food intake of rats fed high protein diets has been reported not to be caused by palatability, high specific dynamic action, nor by lack of carbohydrate in the diets. High protein diet might decrease, the food intake by maintaining the blood sugar at a high level. It has been shown repeatedly that the nutritional value of flour proteins rises with increasing extraction rates of flour during milling (41, 35).

Addition of 5% or 10% refined calcium caseinate to wheat flour was increased the protein content of the bread by almost 5 and 10% respectively, and biological value by 40% (fortified bread 72, control 52). It is concluded that casein fortified bread could be a solution to the problem of protein deficiency among population groups where milk and milk products are too expensive, or accepted (14).

Pomeranz and Finny (84), showed that the influences of glycolipid-protein interactions on the quality of bread with natural and synthetic glycolipds. The addition of glycolipds permitted the production of an acceptable loaf fortified with 16% soy flour, the fortified loaf has approximately 3 times the limiting amino acid content of unfortified bread.

Jansen et al. (49), investigated that the supplementation with various combinations of fish flour and amino acid to white breads. They concluded that the addition of lysine and threonine doubled the utilizability of bread protein with lysine alone responsible for approximately 75% of the increase. Howe et al. (45), measured the protein efficiency ratio (PER) of various grains before and after addition of limiting amino acids. Rats fed with wheat flour containing 8% protein had an average 28 days weight gain of 8 g, and the PER value was only 0.65. Supplementation of the wheat flour with 0.2% lysine hydrochloride brought the weight gain to 35 g and the PER to 1.56, where as supplementation with both L-lysine and L-threonine resulted in a weight gain of 78 g and PER of 2.67, values. Comparable to those obtained for the casein controls. Shehata and Fryer (94) showed that the supplementation of chick pea flours (10 to 20%) to wheat flour, resulted a significantly higher protein efficiency ratio.

Westerman et al. (109), investigated that the addition of defatted wheat germ to the flour produced an increase in growth rate and better reproduction and lactation performance of the rats. Evidence has been obtained that wheat gluten was so poorly balanced in amino acids that the lysine requirement of the rat for maximum growth was increased when the protein was the sole source of lysine in the diet (68).

Processing can cause some loss of lysine, particularly in heat processed proteins. A different type of reaction involving lysine was observed when protein was heated with carbohydrate than when protein was heated alone (68, 20, 9, 25, 75). The reaction of amino acids including lysine, with sugar, commonly referred to as the Maillard reaction, has been reviewed in great detail by Ellis (24).

Jansen et al. (47), have studied the nutritional loss of supplemental lysine that occur during baking, as a function of the duration of the baking time and the supplementation level. From data it was estimated that 15% of the lysine monohydrochloride added to wheat bread was nutritionally lost when the bread was baked 30 min. at 45° F. Increasing the baking time, as expected, increased the loss of both native and supplemental lysine. The presence of moderate amounts of non-fat dry milk was found to increase greatly the nutritive loss of lysine during baking, presumably because of its high content of the reducing sugar D-lactose. In experiments in which 6-14% of non-fat dry milk was added, before baking to bread 20 min. at 45° F, the nutritive loss of lysine was estimated to be 36%.

Rosenberg and Rohdenberg (89), studied the loss of lysine during baking of lysine-fortified breads. The observed loss of lysine in bread due to the baking was about 15%. The losses ranged from 9.5% to 23.8% when bread was baked using flour to which 0.5% D.L lysine hydrochloride was added. Comparing the lysine fortified bread with unfortified bread, they found an average loss of 11%, the loss ranging from 2.4 to 21.8%, using L. lysine hydrochloride- fortified formula, loss was considerably higher, averaging 32% and ranging between 25 and 36.8%. Brown et al. (12), studied the protein quality of commercial breads and reported that the protein quality, as measured by rat growth, was a function of lysine content.

SUPPLEMENTATION OF OIL SEED PROTEINS

Selecting high-protein materials, fortification method, and economic factors are important in consider for fortification (74). Oil seed flours have acceptable flavor and are relatively free of toxic material (60).

Adequate dietary sources of protein are needed to maintain both the concentration and the quality of this nutrient in diets. Animal products, particularly milk, are not always available and are expensive. The possibility of using available and less expensive source of protein of vegetable origin, in fortification of cereals with protein concentrates or amino acids improve the nutritive value of cereal products, and may aid in allevating malnutrition in developing countries (87).

Rooney et al. (87) reported that the protein content of the oil seeds substituted bread was increased by more than 35%. Jones and Divine (52), studied the growth promoting values of the proteins of soy bean, peanut and cotton seed flours were compared by the rat-growth method, and also their values as supplements to the proteins of wheat flour. Soy bean, peanut and cotton seed flours containing protein of high nutritive value and offer an excellent means of supplying dietary protein to extend and particularly replace protein foods of animal origin. These plant proteins are well adopted to enhance the nutritive value of the proteins of wheat flour. The addition of as little as 5 parts of peanut, soy bean or cotton seed flour to 95 parts of wheat flour produced mixtures containing 16 to 19% more protein than wheat flour alone and a protein combination that was definitely superior in its growth promoting value to the same quantity of protein from wheat flour.

PEANUT NUTRITIVE VALUE

Peanuts have a potential for supplying a significant portion of the world's need for edible vegetable oil and protein. Africa, India and Mainland China account for 75% of the world production (112). However peanut flour and meal are by far the largest oil seed protein resource in developing countries like India. Nutritionally, peanut protein is inferior to cotton seeds and soy proteins, but nevertheless it is an available supplement for the predominantly cereal based diet (33).

Payne (76), found that rats fed with bread made from 68% of white flour and 23% peanut flour and butter, salt mixture and yeast, showed a better growth, rate as compared with bread made from white flour in a similar manner.

Subrahmanyan et al. (96), reported that peanut have been used in the form of milk, as a protein isolate, and as defatted peanut flour in a variety of inexpensive food combinations. Animal and human feeding trials of 12 oz of peanut milk curds (fermented milk) to undernourished children resulted in significant increase in growth.

A combination consisting of 85 parts of peanut protein isolate and 15 parts of chick pea protein or flour fortified with minerals and vitamins was effective in improving growth and serum protein of pre-school children receiving a poor vegetarian diet (22).

Keeping in mind that optimum human protein requirements have been suggested to range from 40 to 70 gm. per person per day, protein biological values for peanut flour processed to retain optimal value would be about 45-50 on the NPU scale or 1.5-1.8 by the PER method (64). A supplement of an ounce of defatted peanut flour per day significantly increased gains in weight of children (28).

SOY BEAN NUTRITIVE VALUE

Coppock (16), studied the importance of soy protein in nutrition lies in its high content of essential amino acids, particularly lysine, leucine, and isoleucine. The sulfur containing amino acids, cystine and methionine are in low in soy beans, indicating that methionine is the first limiting amino acid to be considered when using soy products in diet.

Hoover (43), reported from the rats experiments that the protein efficiency ratio of bread was normally in the range of 0.7-1.0 and bread normally will have protein content of 8%. Bread made with 6% soy fortified flour would have a PER of 1.3 and a protein content of 10%. Bread made with 12% soy fortified flour would have a PER of 1.9 and a protein content of 11.5%.

Wolf (113) showed that bread baked with soy product has a PER as good as or slightly better than bread containing non-fat dry milk. Protein can be increased 50% higher than in normal bread, and lysine content can be doubled. Utilization of soy flour to increase the protein content and improve the amino acid balance of the protein contained in baked products have been well recognized for many years. (59).

Sipos et al. (95), reported that the deficiency of sulfur containing amino acids in soy proteins could some times be minimized by combining them with other proteins which were rich in these amino acids. Supplementation with soy proteins provided an excellent means for correcting the lysine deficiency in many protein containing foods of plant origin.

Kon and Markuze (53) reported an improvement in protein quality of bread with the addition of soy flour. In 1935 Baily et al. (6) recommended soy flour as an additive to breads, but early studies often resulted in disappointment because of poor color, flavor and loss in loaf volume.

The improvement in biological value of the protein in soy flour-supplemented bread depends upon the ratio of soy flour to wheat flour used in the formula (39). Westerman et al. (110) studied the improvement value of wheat flour when supplemented with wheat germ or soy flour. They found that both had beneficial effects in improving the growth promoting value of wheat flour.

Pomeranz (83) reported that an excellent bread could be made from blends containing up to 8% soy flour provided a rich formula, a high protein flour, and optimum oxidant level were used. High levels of high-protein oil seed flour or concentrates (from cotton seed, peanut, and soy bean) in bread. Increased in amounts of oil-seed flour in breads with upto 25-40% supplement of wheat flour (without reducing loaf volume) were made possible by substantially increasing the amount of water in the dough.

Hallab et al. (37) reported that the Arabic bread was relatively poor source of protein, being low in lysine. Local flour was supplemented with different levels of chick pea and soy bean flour and 0.25% L. lysine. Arabic bread supplemented with upto 10% soy bean flour showed a high level of acceptability in comparison with unsupplemented bread and was preferred to chick pea supplementation.

Shamsuddin (93), investigated that the nutritional value of white bread supplemented with 12% soy flour. When compared to commercial fortified bread and bread containing 3% non-fat dry milk solids, soy flour-supplemented bread was significantly superior in promoting growth and protein utilization. The protein nutritional value of soy flour supplemented and lysine supplemented breads were not significantly different from that of a casein control diet. Soy flour supplemented bread had higher levels of essential amino acids than white bread, lysine content was almost doubled. Bread supplemented with 14% non-fat dry milk had a lower available lysine content than soy flour supplemented bread. In vitro, digestibility studies showed that soy flour bread was of higher protein quality than white bread.

BIOLOGICAL METHODS

The value of food as a source of protein is determined by the concentration and digestibility of protein, the availability of its amino acid pattern for the synthesis of tissue protein, and its amino acid particularly the proportions of essential amino acids (42).

Mclaughlan and Campbell (62), classified methods of evaluating food proteins as, weight gain, nitrogen balance, net protein utilization, comparison of nitrogen utilization and weight gain, chemical scoring, availability of amino acids, and miscellaneous methods. The criteria used in this investigation, namely protein efficiency ratio.

Protein Efficiency Ratio (PER).

Osborne, Mendel and Ferry originally proposed the use of "grams gain per gram of protein eaten", (protein efficiency) as a measure of the nutritive value of protein for growing rats. In subsequent years, protein efficiency has gained wide acceptance as a measure of the nutritive value of protein; with increasing levels of protein, it reduces a maximum and then slowly declines (40).

Osborne and Mendel (72), evaluated protein quality by using rat growth as an index. They set a pattern for testing which, revised and simplified over the years, remains a method of choice. The criteria of responses was termed "protein efficiency" and was defined as the weight gain per gram of protein consumed. The method uses weanling rats maintained a short growth period. The rats were fed the test product at a specified protein level in an otherwise complete diet.

The factors affecting PER values are level of protein (7, 67), age of rat (15), strain and sex of rat, and length of assay period (8). Chapman et al. (15), specified that male rats, 21 to 23 days old should be about four weeks. Ten percent level of protein in the diet yields an effective means of distinguishing between proteins of varying quality (62).

As specified by the Food and Nutrition Board of the National Research Council, the best conditions include a four week assay period, diets containing 10% protein and providing sufficient amounts of all other essential nutrients, male rats, and ad libitum feeding (32).

Inspite of the advantages of simplicity and wide spread use of PER assay, it is subject to several criticism. Bender (8), pointed out that the assumption that gain in body weight was constant in composition was not necessarily valid, that the results were influenced by food intake, and that PER makes no allowance for maintenance, but assumes that all protein consumed was used for growth. However, important differences have not been encountered in body composition, and variations that may exist in food intake or protein level do not constitute a serious criticism of the method as carried out under standardized conditions (32).

MATERIAL AND METHODS

Peanut flour (defatted), and soy flour (defatted) were supplied by Gold Kist peanuts, Florida and Ardex 550, Archer-Daniel-Midland, Company Kansas City. Wheat flour was milled from hard red winter wheat on a Miag Multimat in the department. Proximate analysis of flour were performed as described by A.A.C.C methods (1), except that fat was determined by the A.O.C.S. method (Aa4-38) (5), using petroleum ether as the extracting solvent. Protein contents for all samples were converted by N x 6.25 except N x 5.7 for wheat flour (Table 1).

Calcium and sodium stearoyl-2 lactylates (CSL and SSL) and ethoxylated mono glycerides (EM), and sucrose monopalmitate (SMP), are products of the C. J. Patterson Company, Colonial Sugar Company, and Dai-Nippon Sugar Manufacturing Company, respectively. SSL was used in most of the studies, because more countries have approved it as a dough conditioner for bakery products than the others.

Amino acids were determined by the procedure of Waggle et al. (106). Bread samples, after being dried and ground, were hydrolyzed in excess of 6N Hcl for 22 hr. Essential amino acids were measured in a Beckman 120 B amino acid analyzer.

Farinograms:

The farinograph measures and records the resistance of a dough to mixing. It is used to evaluate the absorption of water by flour and to determine the stability and other characteristics of dough during mixing. Two basically different methods are in common use. Constant dough weight

TABLE 1. PROXIMATE ANALYSES OF PEANUT FLOUR, SOY FLOUR AND WHEAT FLOUR (WET BASIS)

SAMPLE	MOISTURE %	PROTEIN %	ASH %	FAT %
Peanut flour	8.6	56.7	4.5	1.0
Soy flour	7.6	51.2	7.8	1.1
Wheat flour	12.0	11.0	0.49	---

procedure and constant flour weight procedure. The two procedures may not yield identical results.

These farinograms were obtained by the constant dough weight method (A.A.C.C). Water absorption adjusted to obtain a dough having a maximum consistency of 500 Brabender Units (B.U). Whenever dry flours were treated with SSL, EM, and SMP, the dry ingredients were blended for 5 minutes in a farinograph bowl before adding distilled water and mixing.

Baking Test:

The K-State (Kansas State University) process for making high-protein bread was used (100). The formula consists of flour (14% moisture content), 12% (variable) of soy flour or other protein rich food stuff, 3% yeast, 5% sugar, 2% salt, variable water, variable bromate and 0.5% surfactant (% on a flour basis). All the ingredients were combined at room temperature in a Hobart mixer, and mixed at first speed (low) for one minute and then at second speed (medium) to optimum dough development. The dough was then scaled into 500 gram pieces, rounded, and let rested for 40 minutes at 86° F and 85% R.H, to height (1.5 cm) over the pan. Baking was at 425° F for 25 minutes.

In this study, used 70 ppm, potassium bromate (flour basis) for all the baking tests. Loaf weight and volume averaged from duplicates were measured with in 10 minutes, after bread was removed from the oven. Specific loaf volume was then calculated from the average loaf weight and volume. Specific loaf volume is important for bread's marketability. Generally in the U.S.A; specific loaf volume of marketable bread (one pound loaf) should be at least

6.00 c.c/gram or have a volume of 2722 c.c, with acceptable appearance, crumb, texture, and grain. Bread was scored from 1 to 10, 18 hrs. after baking. Finished bread scoring less than 5 was regarded as unsatisfactory. Most of the baking tests were repeated at least once on a different day to substantiate results.

Unless otherwise indicated, the amount of peanut flour or soy flour or blend of peanut-soy flours added to wheat flour for baking and farinographic test was expressed as percentage of wheat flour (baker's percentage).

In this study, used different levels of peanut flour (10.0, 15.0 and 25.0%), 15.0% peanut flour as the standard (according to the protein basis) for all the baking tests used in this study. Breads were baked with the following percentages; (1), white flour bread. (2), 15.0% peanut flour bread. (3), 5.0% peanut flour-11.0% soy flour bread. (4), 10.0% peanut flour-5.5% soy flour bread. (5), 16.6% soy flour bread.

Staling Test

Staling (firmness) was tested by following changes in crumb firmness with a recording strain gauge that registered the pressure (Kg) required to depress a one-inch thick slice to 0.1-inch thick with a plastic plunger 1 inch in diameter. Four 1-inch slices were taken from the middle portion of each of three loaves that had been wrapped and sealed, and stored at room temperature (about 25^{o} C) for 1, 3, and 5 days. One pressure (kg) reading was taken from the center of each slice, averaged readings were reported.

Flour and Crumb Colors:

Flour and crumb color were evaluated with Agtron Multi-Chromatic Abridged Reflectance Spectrophotometer Model M-300 A with monochromatic spectral lines; red (640 nm), green (546 nm) and yellow (585 nm). The instrument was standardized with standard disc M-68 to read 100 and with standard disc 00 to 0. Flour sample was packed in a transparent cup (3.7 cm-height, 5 cm-diameter) for color measurements. For bread sample, a slice (about $\frac{1}{2}$ inch thick), taken from the middle portion of a loaf, was used for measurements.

Nutritional Study

The nutritive value of wheat breads supplemented with 15.0% peanut flour, 5.0% peanut-11.0% soy flour, 10.0% peanut flour-5.5% soy flour, 16.6% soy flour and control white bread, were determined using weanling rats. Sodium stearoyl-2 lactylate (SSL) at 0.5% level was added to the baking formula, to enhance the physical characteristics of the bread. The five bread samples used in this study were identified in Table 2.

The breads were sliced and dried in a heated air oven at 50°C for 24 hours and then ground to a uniform particle size (20 mesh) for incorporating into experimental diets. The proximate composition of breads were analyzed for moisture, crude protein, ash and fiber (70). All diets were prepared using ground bread.

A separate vitamin and mineral premix were prepared according to NRC formula to support optimum rat growth. Two percent vegetable oil was added to each diet to improve texture and decrease dustiness. A control diet was formulated using casein, starch, and the vitamin and mineral mixture, sugar and cellulose fiber as listed in Tables 3 and 4. Table 5 shows the composition of the six diets used in this study.

TABLE 2. PROXIMATE ANALYSES OF PEANUT, SOY FLOUR, PEANUT-SOY FLOUR BLEND AND WHITE BREADS WITH 0.5% SSL (MOISTURE FREE BASIS)

SAMPLE	MOISTURE %	ASH %	FAT %	PROTEIN %	PROTEIN DRY BASIS %	% PROTEIN INCREASE
White bread	8.1	2.4	0.4	12.5	13.64	--
15.0% P.F. bread	8.5	2.7	0.3	18.4	20.10	47.36
5.0% P.F. - 11.0% S.F. bread	8.8	3.0	0.4	18.6	20.39	49.48
10.0% P.F. - 5.5% S.F. bread	8.4	3.0	0.5	18.5	20.19	48.02
16.6% S.F. bread	8.6	3.2	0.3	18.4	20.13	47.58

TABLE 3. COMPOSITION OF VITAMIN PREMIX FOR EXPERIMENTAL DIETS

INGREDIENTS	GRAMS PER 4 kg. DIET g
Vitamin A (10,000 IU/g)	8.000
Vitamin D3 (15,000 IU/g)	2.700
Alpha Tocopheral Acetate (25%)	1.400
Menadione Sodium Bisulphate	0.230
Thiamine Hcl	0.050
Riboflavin	0.100
Pyridoxin	0.048
Niacin	0.600
Calcium Pantothenate	0.320
Choline Chloride	32.000
Vitamin B12	0.200
Carrier (starch)	36.352

TABLE 4. COMPOSITION OF MINERAL PREMIX FOR EXPERIMENTAL DIETS

TREATMENT NO.	INGREDIENTS	AMOUNT PER 4 kg. DIET
		g.
1 (control)	Dicalcium phosphate	72.00
	Calcium carbonate	10.00
	Salt (Nacl)	4.00
	Potassium chloride	5.80
	Trace minerals[c]	2.00
	Starch (carrier)	26.12
2,3,4,5[a]	Dicalcium phosphate	64.00
	Calcium carbonate	15.00
	Salt (Nacl)	16.00
	Trace minerals[c]	2.00
	Starch (carrier)	35.00
6[b]	Dicalcium phosphate	64.00
	Calcium carbonate	15.00
	Salt (Nacl)	16.00
	Potassium chloride	2.00
	Starch (carrier)	9.72
	Trace minerals[c]	13.28

[a]Treatments 2,3,4, and 5 were 15.0% peanut flour bread, 5.0% peanut-11.0% soy flour bread, 10.0% peanut-5.5% soy flour bread and 16.6% soy flour bread.

[b]Treatment 6 was casein diet.

[c]CCC Trace minerals: Calcium Carbonate Company, Quincy, Ill. (mg/1000 g diet; Mn, 0.05; Fe, 0.05; Cu, 0.005; Zn, 0.025; Co, 0.005; I, 0.0015; Ca, 0.058).

TABLE 5. DIET COMPOSITION

SNO	DIET	% PROTEIN IN BREAD (WET BASIS)	% BREAD TO GIVE 10% PROTEIN	FAT (OIL) %	VIT. MIX. %	MIN. MIX. %	STARCH TO MAKE 100%	CASEIN %	SUGAR (SUCROSE) %	NON-NUTRITIVE FIBER CELLULOSE (ALPHA CELL) %
1	White Bread	12.5	80	2	2	3	13	---	---	---
2	15% P.F. Bread	18.4	54.34	2	2	3	38.16	---	---	---
3	5% P.F. + 11% S.F. Bread	18.6	53.76	2	2	3	39.24	---	---	---
4	10% P.F. + 5.5% S.F. Bread	18.5	54.05	2	2	3	38.95	---	---	---
5	16.6% S.F. Bread	18.4	54.34	2	2	3	38.66	---	---	---
6	Casein	82	---	2	2	3	77.00	12.20	2.80	1.0

Design of Animal Feeding Experiments:

A randomized complete block-design was used. The growth study was conducted using 25 day-old male weanling rats (Charles River strain) bred and raised at the animal nutrition laboratory of the Department of Biochemistry, Kansas State University, were used.

A completely randomized experimental design with eight rats per treatment was used for this study. The average weights of the rats were between 77-84 grams. The rats were housed in individual wire-bottom cages in an environmentally controlled laboratory. The test diets and water were given *ad libitum*. Fresh water was given every second day, and the feed cups were checked every day and filled according to need during the 3- weeks test period. During the study, the weight and feed consumption were recorded weekly for each individual rats. Feed wastage (usually small) was measured and subtracted from the consumption data.

RESULTS AND DISCUSSION

This study was designed to assess the baking performances and the nutritional value of high protein breads fortified with peanut and soy flours.

The reheological properties of wheat flour-water dough changed after being fortified with peanut or soy flour, as shown in Table 6. Oil seed flours added at high levels caused dramatic reduction in loaf volume with a concomitant decrease in crumb quality (61).

Farinograph:

Dough absorption increased, while stability progressively decreased as fortification increased. Developing (peak) time also decreased somewhat with fortification. The reduced stability and developing time indicated that peanut or soy flour weakens the dough structure. The weakening was less with soy flour than with peanut flour.

Sodium stearoyl-2 lactylate, though it had little effect on absorption markedly increased dough stability and development time, based on the farinographic data. The dough-strengthening action of SSL seems responsible, at least in part, for improving the baking performance of wheat flour fortified with peanut or soy flour (Table 7) (5).

Baking Performance of Fortified Flour:

Preliminary tests showed that the K-State process was better than the conventional straight-dough method such as described by Robinson (86), or the A.A.C.C method 10-10(1), for making breads from wheat flour

TABLE 6. FARINOGRAPHIC CHARACTERISTICS OF WHEAT FLOUR FORTIFIED WITH INDICATED PERCENTAGE OF PEANUT FLOUR, SOY FLOUR AND BLEND OF PEANUT-SOY FLOURS, WITH OR WITH-OUT 0.5% SSL.

Bread sample	SSL %	Abs. %	A. time min.	P. time min.	Departure time min.	Dough stability min.
Wheat flour bread	0	59.0	0.50	6.35	10.25	9.75
	0.5	58.0	0.50	7.85	13.25	12.75
10.0% P.F bread	0	71.4	1.25	6.00	9.00	7.75
	0.5	70.2	1.50	7.00	9.50	8.00
15.0% P.F bread	0	75.2	3.00	5.20	9.35	5.80
	0.5	74.6	3.50	6.30	10.50	7.00
25.0% P.F bread	0	83.4	3.50	4.50	8.25	4.75
	0.5	83.0	3.30	6.00	10.00	6.70
5.0% P.F-11.0% S.F bread	0	75.8	2.25	5.45	8.25	6.00
	0.5	74.8	2.40	6.30	9.25	6.85
10.0% P.F-5.5% S.F bread	0	75.6	2.00	6.00	8.40	6.40
	0.5	75.0	2.30	6.40	9.50	7.20
16.6% S.F. bread	0	76.8	2.40	5.50	9.40	7.00
	0.5	76.0	2.50	6.30	10.50	8.00

TABLE 7. MIXING CONDITIONS, AND SPECIFIC LOAF VOLUMES AND GRAIN SCORES OF BREADS FROM WHEAT FLOUR FORTIFIED WITH INDICATED PERCENTAGES OF PEANUT FLOUR

FORTIFIED LEVEL %	ABS. %	MIX. MIN.	SURFACTANT 0.5% ADDED	SP. VOLUME c.c./g.	GRAIN SCORE
10	72	5	0	5.26	5
	72	5	EM	6.25	8
	72	5	SMP	6.53	7
	72	5	SSL	6.26	8
15	74	5	0	4.71	3
	74	5	EM	5.65	6
	74	5	SMP	6.00	7
	74	5	SSL	5.72	7
25	84	7	0	3.01	2
	84	7	EM	4.33	4
	84	7	SMP	4.57	5
	84	7	SSL	3.88	3

fortified with peanut and soy flours. But even with the K-State process, using more than 10% peanut flour or soy flour as a fortifier drastically depressed loaf volume and grain score of the finished bread which would be no longer be considered acceptable.

Different levels of peanut flour were fortified with wheat flour. On the other hand, by adding 0.5% SSL, got acceptable breads with specific loaf volume of more than 5.0 c.c/g, and grain score of more than 5 could be prepared from wheat flour fortified with up to 15.0% peanut flour, soy flour or blend of peanut-soy flours (Fig. 1).

In this study, first, baked different levels of peanut flour (10.0, 15.0, and 25.0%) fortified with wheat flour. The results showed that acceptable bread could be prepared from up to 15.0% peanut flour fortified with wheat flour; where as the fortification of 25.0% peanut flour drastically reduced, the loaf volume and grain score. So, 15.0% peanut flour fortified bread was used as the standard for this study.

Although the specific loaf volume of 6.00 c.c/g, is generally used to gauge regular white bread's marketability in the U.S., baking industry, the standard is arbitrary. Breads with specific loaf volume of more than 4.5 were quite acceptable in many countries. That would permit raising the fortification level of peanut and soy flour products much higher.

In this study most of the breads fortified with peanut flour, soy flour and blend of soy-peanut flours with a surfactant have a specific loaf volume of more than 5 and grain score 5. Wheat flour fortified with 15.0% peanut flour bread has a better specific loaf volume than 16.6% soy fortified bread. Results showed that the blend of 10.0%

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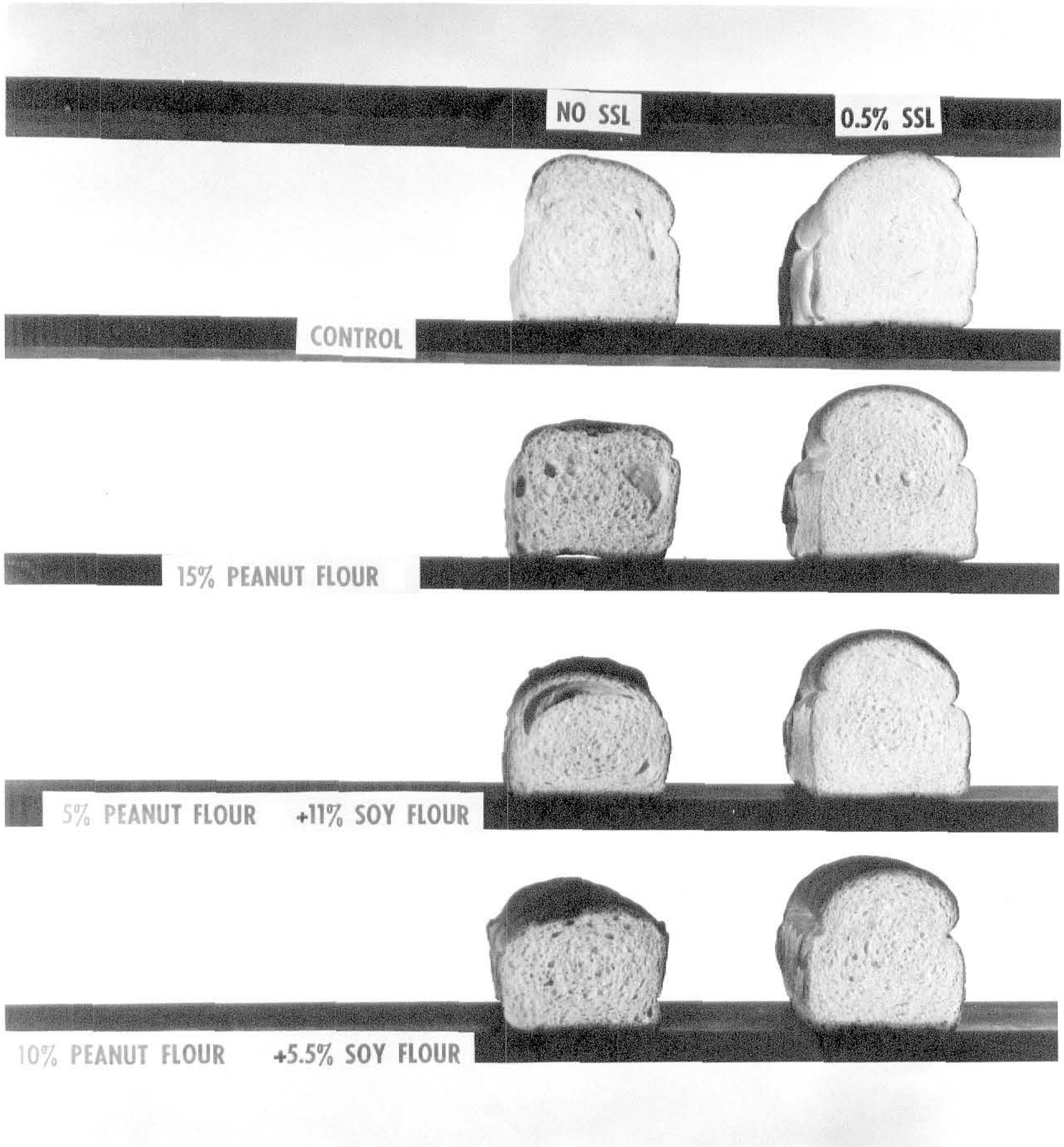

Fig.1. Breads from wheat flour and indicated blends.

peanut flour-5.5% soy flour bread had a significant increase in specific loaf volume and grain score over 5.0% peanut flour-11.0% soy flour bread. White bread had the highest specific loaf volume and grain score, compared to other breads.

Effect of Surfactants:

SSL, EM and SMP, and their improving effects on the loaf volume and grain score of breads from wheat flour fortified with different levels of peanut flour, soy flour and blend of peanut-soy flour breads. All the surfactants tested effectively improved baking quality (Table 7).

First suspended each surfactant (SSL, EM, and SMP) in 100 ml. water at 54°C and then mixed it with other ingredients into dough for bread making. Among the three surfactants, SMP often gave the fortified bread a slightly larger loaf volume, but SSL provided the bread with a little better grain score. The findings with peanut fortified breads supports other's observations with soy fortified bread (Pomeranz (82), Tsen et al. (101), Finney and Shogren (30), Tsen and Hoover (103). For nutritional study, used only SSL, because it is a more widely used dough conditioner.

In addition, surfactants, shortened proofing time for the fortified dough. Doughs, fortified with 10.0 to 25.0% peanut flour or soy flour but with no SSL, took about 90 min. proofing time to reach template of 1.5 cm. above the center of a pan, where as surfactants treated doughs reached the same height in about 70 min.

Fortified Bread's Protein Content and Quality:

Table 8 shows that the breads protein contents were raised to 30.4, 54.0 and 68.8% over the control bread by fortifying it, respectively

TABLE 8. MIXING CONDITIONS, LOAF VOLUME, GRAIN SCORES, AND PROTEIN CONTENTS OF BREADS FORM WHEAT FLOUR FORTIFIED WITH INDICATED PERCENTAGE OF PEANUT FLOUR, PEANUT-SOY FLOURS WITH 0.5% SSL.

Fortifier(s)	Dough		Bread	
	Abs. %	Mix. min.	Sp. Vol (score) c.c/g.	Protein (% increase) % (dry basis)
0	60	7	6.60(9)	13.8
Peanut flour				
10.0%	75	5	6.26(8)	18.00(30.4)
15.0%	79	5	5.72(7)	20.10(54.0)
25.0%	87	7	3.88(3)	23.30(68.8)
Peanut-soy flour				
5.0%-11.0%	75	5	5.23(7)	20.39(56.2)
10.0%-5.5%	75	5	6.16(7)	20.13(54.2)

with 10.0, 15.0, and 25.0% peanut flour. The increase was quite impressive.

Because peanut protein is deficient in methionine, lysine, isoleucine (Evans et al. (26)) and threonine (Mcosker, (63), Anderson and Warnie (4). Wheat flour fortified with a blend of peanut-soy flours to improve the bread's protein quality. Mixing conditions and baking qualities of such fortified breads were given in Table 9. Their protein contents were comparable that of bread fortified with 15.0% peanut flour.

To understand the benefit of such fortification, the amino acid contents of peanut flour and soy flour were analyzed (Table 10). Soy protein contains more lysine, threonine, leucine, isoleucine, and valine than peanut protein does, so adding soy flour should improve the protein quality (amino acid pattern) of peanut fortified bread. With the adequate supply of sulfur containing amino acids from wheat flours, the nutritional value of the fortified breads, particularly peanut-soy fortified ones, would exceed that of wheat bread.

Storage Test (Staling):

Several kinds of breads, described in Table 9, were prepared for storage tests. Peanut fortified bread retained softness well with SSL, peanut fortified breads were much softer than wheat breads during storage. When breads were fortified with a blend of peanut-soy flours, however, they firmed rapidly, particularly the one with 5.0% peanut-11.0% soy flour (Tables 11 and 12).

TABLE 9. MIXING CONDITIONS AND SPECIFIC LOAF VOLUMES AND GRAIN SOCRES OF BREADS FROM WHITE BREAD, PEANUT FLOUR BREAD, SOY FLOUR BREAD, BLEND OF PEANUT AND SOY FLOUR BREADS WITH 15.0% PEANUT PROTEIN LEVEL.

FORTIFIED LEVEL %	ABS. %	MIN. MIX.	SURFACTANTS 0.5% ADDED	SP. VOL. c.c/g.	GRAIN SCORE
White Bread	60	7	0	5.95	6
	60	7	EM	7.13	7
	60	7	SMP	7.42	8
	60	7	SSL	6.60	9
15.0% P.F. Bread	74	5	0	4.71	3
	74	5	EM	5.65	6
	74	5	SMP	6.00	7
	74	5	SSL	5.72	7
5.0% P.F-11.0% S.F. Bread	75	5	0	4.35	5
	75	5	EM	5.23	7
	75	5	SMP	5.59	8
	75	5	SSL	5.95	9
10.0% P.F-5.5% S.F. Bread	75	5	0	4.84	5
	75	5	EM	6.03	6
	75	5	SMP	6.53	8
	75	5	SSL	6.23	7
16.6% S.F. Bread	75	5	0	3.89	4
	75	5	EM	5.02	7
	75	5	SMP	5.62	8
	75	5	SSL	4.26	6

TABLE 10. PROTEIN AND AMINO ACID COMPOSITION OF WHEAT FLOUR, PEANUT FLOUR AND SOY FLOUR.

	WHEAT FLOUR	PEANUT FLOUR	SOY FLOUR
Protein	11.00[d]	56.71[a]	51.20[a]
Amino acid[b]			
Lysine	1.45	3.66	5.56
Histidine	1.53	2.28	2.17
Arginine	2.76	11.64	6.58
Aspartic acid	4.17	11.92	13.79
Threonine	2.55	2.49	4.24
Serine	4.67	4.68	5.95
Glutamic acid	35.05	18.96	22.18
Proline	13.03	3.58	6.49
Glycine	3.36	5.72	4.70
Alanine	2.84	3.68	4.76
Cystine[c]	3.05	2.08	2.30
Valine	3.87	3.27	6.05
Methionine[c]	0.96	0.81	1.57
Isoleucine	3.50	3.20	5.02
Leucine	6.03	6.35	8.18
Tyrosine	2.42	4.07	3.58
Phenylalanine	4.59	5.01	5.62

[a]percentage protein (N x 6.25)

[b]Grams amino acid per 100 grams Kjeldahl protein

[c]Cystine and methionine values determined by performic acid oxidation, following procedure of Moore (66).

[d]percentage protein (N x 5.7)

TABLE 11. AVERAGE COMPRESSIMETER READINGS (Kg.) STORED BREADS MADE FROM WHEAT FLOUR AND INDICATED BLENDS

FORTIFIED BREAD	DAYS STORED					
	NO SSL			0.5% SSL		
	1	3	5	1	3	5
White Bread	6.12	6.79	7.46	5.53	6.14	6.55
15.0% P.F. Bread	6.33	7.55	7.87	3.05	3.23	3.45
16.6% S.F. Bread	10.70	11.05	12.95	9.55	10.40	11.48
5% P.F. + 11.0% S.F. Bread	9.53	9.76	12.13	7.33	8.38	9.37
10% P.F. + 5.5% S.F. Bread	8.20	9.32	9.84	6.68	6.90	7.20

TABLE 12. AVERAGE COMPRESSIMETER READINGS (Kg.) OF STORED BREADS FROM WHEAT FLOUR AND INDICATED BLENDS

BREAD SAMPLE	DAYS STORED											
	NO SSL			0.5% SSL			0.5% EM			0.5% SMP		
	1	3	5	1	3	5	1	3	5	1	3	5
White bread	6.1	6.7	7.4	5.5	6.1	6.5	3.7	4.4	5.0	3.5	3.6	4.5
15.0% P.F.	6.3	7.5	7.8	3.0	3.2	3.4	4.0	4.2	5.2	3.9	3.9	4.5
5.0% P.F-11.0% S.F	9.5	9.7	12.1	7.3	8.3	9.3	6.4	6.4	7.2	5.0	5.3	5.7
10.0% P.F-5.5% S.F	8.2	9.3	9.8	6.6	6.9	7.2	4.5	5.9	6.4	3.9	4.3	5.3
16.6% S.F	10.7	11.0	12.9	9.5	10.4	11.4	6.3	7.3	7.4	5.1	6.5	6.7

Crumb Colors of Fortified Breads:

Flour and crumb colors, measured by Agtron Multi Chromatic Abridged Reflectance Spectrometer were listed in Table 13. The crumb of peanut fortified breads appeared much darker than that of wheat bread and soy bread. Two factors were mainly responsible for the dark-coloration. First, peanut flour was darker than wheat or soy flour. Second, more extensive browning reaction likely took place during baking peanut-fortified bread than for wheat bread.

Nutritional Study:

Results of the proximate analysis of breads were given in Table 14. The values indicated that the supplementation of different levels of peanut and soy flours to the white bread increased the protein content. The amino acid contents of experimental diets were analyzed (Table 15).

Table 14 indicated that bread's protein contents were raised, 54.0, 54.7, 56.2, 54.2% over the controlled bread by fortifying it, respectively, with 15.0% peanut flour, 5.0% peanut flour-11.0% soy flour, 10.0% peanut flour-5.5% soy flour and 16.6% soy flour. The increase was quite impressive, because peanut protein is deficient in methionine, lysine, isoleucine and threonine. Wheat flour fortified with a blend of peanut-soy flours to improve the breads protein quality. Soy protein contains more lysine, threonine, leucine, isoleucine and valine than peanut protein does, so adding soy flour should improve the protein quality (amino acid pattern) of peanut fortified bread. However the fortified bread, would still be deficient in lysine and threonine.

TABLE 13. AGTRON READINGS (RED AND YELLOW) OF WHEAT FLOUR, PEANUT FLOUR, SOY FLOUR, AND CRUMBS OF INDICATED BREADS

SPECIFICATION	WHEAT FLOUR	PEANUT FLOUR	SOY FLOUR
Red	54	43	50
Yellow	45	32	40

	BREAD (CRUMB)							
	White Bread		15.0% P.F Bread		5.0% P.F-11.0% S.F. Bread		10.0% P.F-5.5% S.F Bread	
	NO SSL	0.5% SSL	NO SSL	0.5% SSL	NO SSL	0.5% SSL	NO SSL	0.5% SSL
Red	98	100	59	83	65	88	62	80
Yellow	87	97	45	70	49	74	46	65

TABLE 14. ANALYSIS OF BREAD SAMPLES USED IN NUTRITIONAL STUDY (MOISTURE FREE BASIS)

TREATMENT	MOISTURE	PROTEIN		ASH	FAT
		WET BASIS	DRY BASIS (% INCREASE)		
	%	%	%	%	%
White Bread	8.1	12.5	13.5	2.4	0.4
15.0% P.F. Bread	8.5	18.4	20.10(54.0)	2.7	0.3
5.0% P.F-11.0% S.F. Bread	8.8	18.6	20.39(56.2)	3.0	0.4
10.0% P.F-5.5% S.F. Bread	8.4	18.5	20.19(54.7)	3.0	0.5
16.6% S.F. Bread	8.6	18.4	20.13(54.2)	3.2	0.3

TABLE 15. PROTEIN AND AMINO ACID COMPOSITION OF BREAD SAMPLES USED IN NUTRITIONAL STUDY.

	Identification of Breads				
	White bread	15% P.F	5% P.F-11% S.F	10% P.F-5.5% S.F	16.6% S.F
Protein[a]	12.5	18.40	18.50	18.60	18.40
Amino acids[b]					
Lysine	1.16	1.38	1.86	1.53	2.86
Histidine	1.29	1.28	1.70	1.08	1.82
Arginine	1.76	5.75	4.22	4.31	3.92
Aspartic acid	4.20	7.47	7.61	7.68	7.69
Threonine	2.82	3.12	3.68	3.30	3.80
Serine	4.97	5.14	5.07	5.17	5.22
Glutamic acid	37.02	30.46	32.29	31.07	29.63
Proline	13.57	9.35	10.18	11.05	10.22
Glycine	3.56	4.57	3.90	4.35	3.99
Alanine	3.01	3.81	3.24	3.60	3.65
Cystine[c]	2.39	3.57	2.19	2.58	3.15
Valine	3.93	4.57	4.38	4.26	3.54
Methionine[c]	0.96	0.80	1.18	0.70	1.01
Isoleucine	3.68	3.00	4.10	3.54	4.17
Leucine	6.68	6.72	7.59	6.90	7.64
Tyrosine	1.91	2.64	2.69	2.41	2.70
Phenylalanine	4.78	5.65	5.06	5.03	4.72

[a]Percent protein (N x 6.25)

[b]Grams of amino acid per 100 grams Kjeldahl protein.

[c]Cystine and methionine values determined by performic acid oxidation, following procedure of Moore (66).

Gain in body weights, feed consumption, and protein utilization for rats fed experimental diets for the 3-week test period were summarized in Table 16. This study has demonstrated that fortification of oil seed flours for white bread, would provides a valuable food supplement, superior to white bread, as indicated that fortified breads have more nutritional value than the control, from the results of PER, weight gain and feed consumption. Soy fortified bread (16.6%) had more nutritional value than other diets from the results of PER, weight gain and feed consumption.

Cumulative Weight Gain:

The cumulative weight gain of rats fed the six diets, illustrated in Fig. 2. Rats fed casein diet had the highest rate of growth. Rats fed casein diet had the highest rate of growth. Rats fed with 16.6% soy flour fortified bread had significantly ($P < 0.05$) higher growth than the rest of the groups fed with 5.0% peanut-11.0% soy flour, 10.0% peanut-5.5% soy flours, 15.0% peanut flour and wheat flour (control) breads. Groups of rats fed bread containing 5.0% peanut flour-11.0% soy flour and 10.0% peanut flour-5.5% soy flour, gained significantly ($P < 0.05$) more weights than with breads containing 15.0% peanut flour and white flour breads. Wheat flour fortified with 15.0% peanut flour bread, gained significantly ($P < 0.05$) more weight over white bread (Table 17).

Feed Consumption:

Results in Table 18, revealed a significant ($P < 0.05$) increase in feed consumption by the group fed 16.6% soy fortified bread when compared

TABLE 16. AVERAGE WEIGHT GAIN, FEED CONSUMPTION, PROTEIN EFFICIENCY RATIO, AND FEED CONVERSION FOR RATS FED EXPERIMENTAL DIETS

TREATMENTS	WEIGHT GAIN[a] (g)	FEED CONSUMPTION[b] (g)	PER[c]	FEED CONVERSION[d]
White Bread	25.12	220.37	1.14	8.77
15.0% P.F. Bread	32.12	242.25	1.32	7.54
5.0% P.F-11.0% S.F. Bread	56.87	300.00	1.89	5.27
10.0% P.F-5.5% S.F. Bread	51.87	288.62	1.79	5.56
16.6% S.F. Bread	69.00	320.62	2.15	4.64
Casein	71.87	290.37	2.47	4.04

[a]Average gain per rat 0-3 weeks, LSD 10.82, F-value 24.05

[b]Grams of feed consumed 0-3 weeks, LSD 28.82, F-value 12.59

[c]Grams weight gain per gram of protein consumed, LSD 0.28, F-value 23.43

[d]Grams feed per gram of weight gain.

THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

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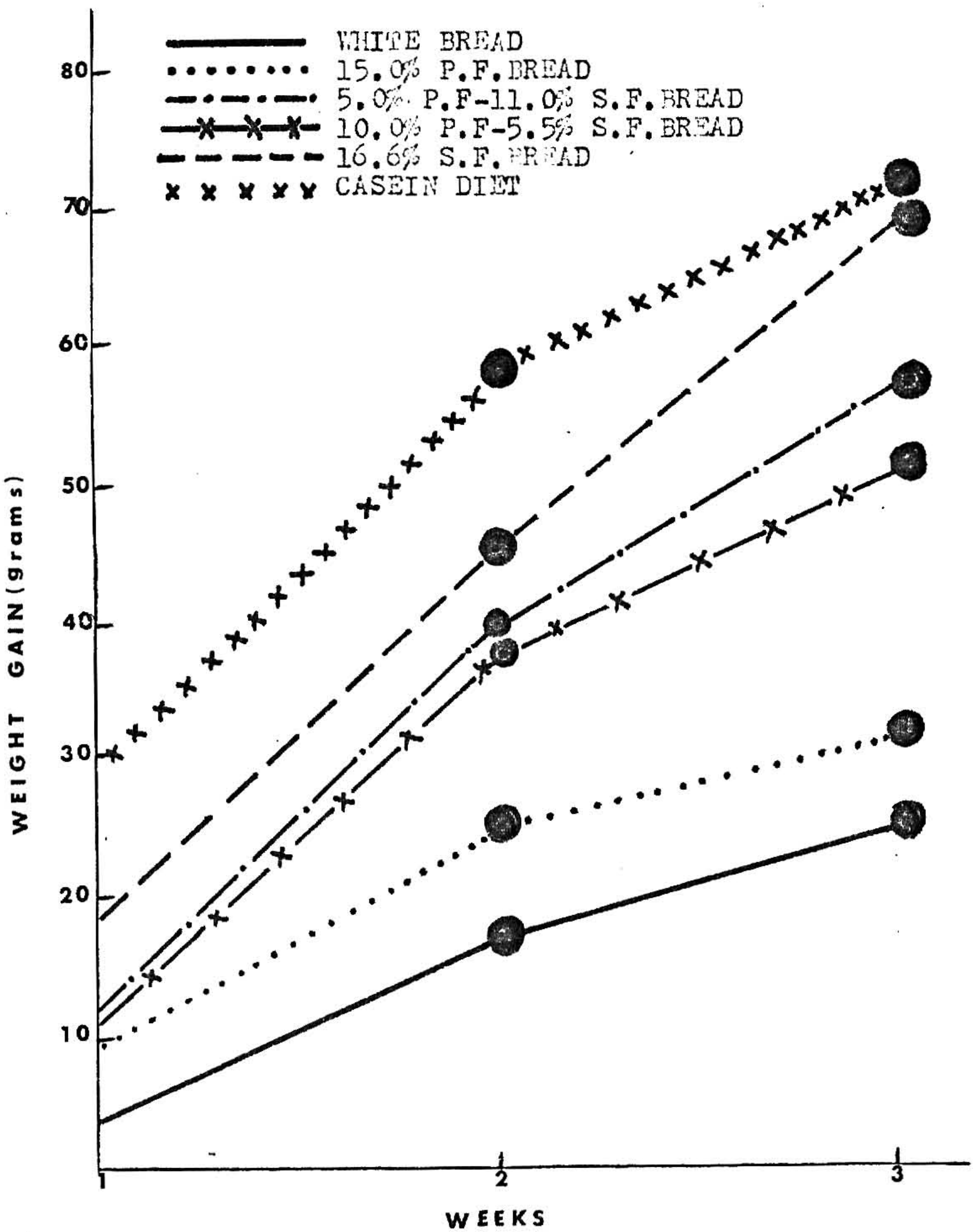

Fig.2. Cumulative weight gain of rats

TABLE 17. MEAN CUMULATIVE WEIGHT GAINS OF RATS[a] FED THE SIX DIETS

TREATMENT	INITIAL WEIGHT (g.)	FINAL WEIGHT (g.)	CUMULATIVE WEIGHT GAIN (g.)
White Bread	81.37	106.50	25.13
15.0% P.F. Bread	81.62	114.00	32.38
5.0% P.F-11.0% S.F. Bread	80.50	137.37	56.87
10.0% P.F-5.5% S.F	80.62	132.50	51.88
16.6% S.F. Bread	80.12	149.12	69.00
Casein	80.25	152.12	71.87

Analysis of variance:

Source	Sum of Squares	DF	Mean Square
Treatment	16551.50	6	2758.58
Error	5619.00	49	114.67
Total	22170.50	55	

LSD Least Significant Difference at the 5% level

[a]Eight rats pèr diet

TABLE 18. MEAN FEED CONSUMPTION OF SIX DIETS[a]

TREATMENTS	FEED CONSUMED (g.)
White Bread	220.37
15.0% P.F. Bread	242.25
5.0% P.F-11.0% S.F Bread	300.00
10.0% P.F-5.5% S.F Bread	288.62
16.6% S.F. Bread	320.62
Casein	290.37

Analysis of variance

Source	Sum of Squares	DF	Mean Square
Treatment	61495.50	6	10249.25
Error	39866.00	49	813.60
Total	101362.00	55	

[a]Eight rats per diet.

LSD: - Least Significant Difference at the 5% level.

to other diets. The next significant difference in increased feed consumption were observed in breads containing 5.0% peanut flour-11.0% soy flour, 10.0% peanut flour-5.5% soy flour and casein diet, compared to 15.0% peanut flour and white flour breads. Rats fed 16.6% soy fortified bread had the highest average feed intake (320.62 g.). The results were illustrated in Fig. 3. Amino acid deficiencies in the white flour and 15.0% peanut flour breads, may have also resulted in lower feed consumption. Wheat flour fortified with 15.0% peanut flour bread had higher feed consumption than white flour bread.

Protein Efficiency Ratio:

The protein efficiency ratio results, as shown in Tables 16 and 19. The protein efficiency ratios follow closely the weight gain responses. Casein diet had the highest protein efficiency ratio value, compared to other diets. Wheat flour fortified with 16.6% soy flour bread was significantly ($P < 0.05$) higher PER value than other diets. The PER values of 5.0% peanut-11.0% soy flour and 10.0% peanut-5.5% soy flour fortified breads were significantly higher than those of diets containing 15.0% peanut and wheat flour breads. The PER values of 15.0% peanut flour fortified bread was higher than wheat flour bread (control).

The increase in PER values due to supplementation with soy flour has also been observed by several other workers (52, 105), thus confirming an improvement in protein quality of bread by addition of soy and peanut flours. The results were illustrated in Fig. 4.

The addition of soy flour to bread increased the protein content of bread. An increase in the protein content of diets increases weight

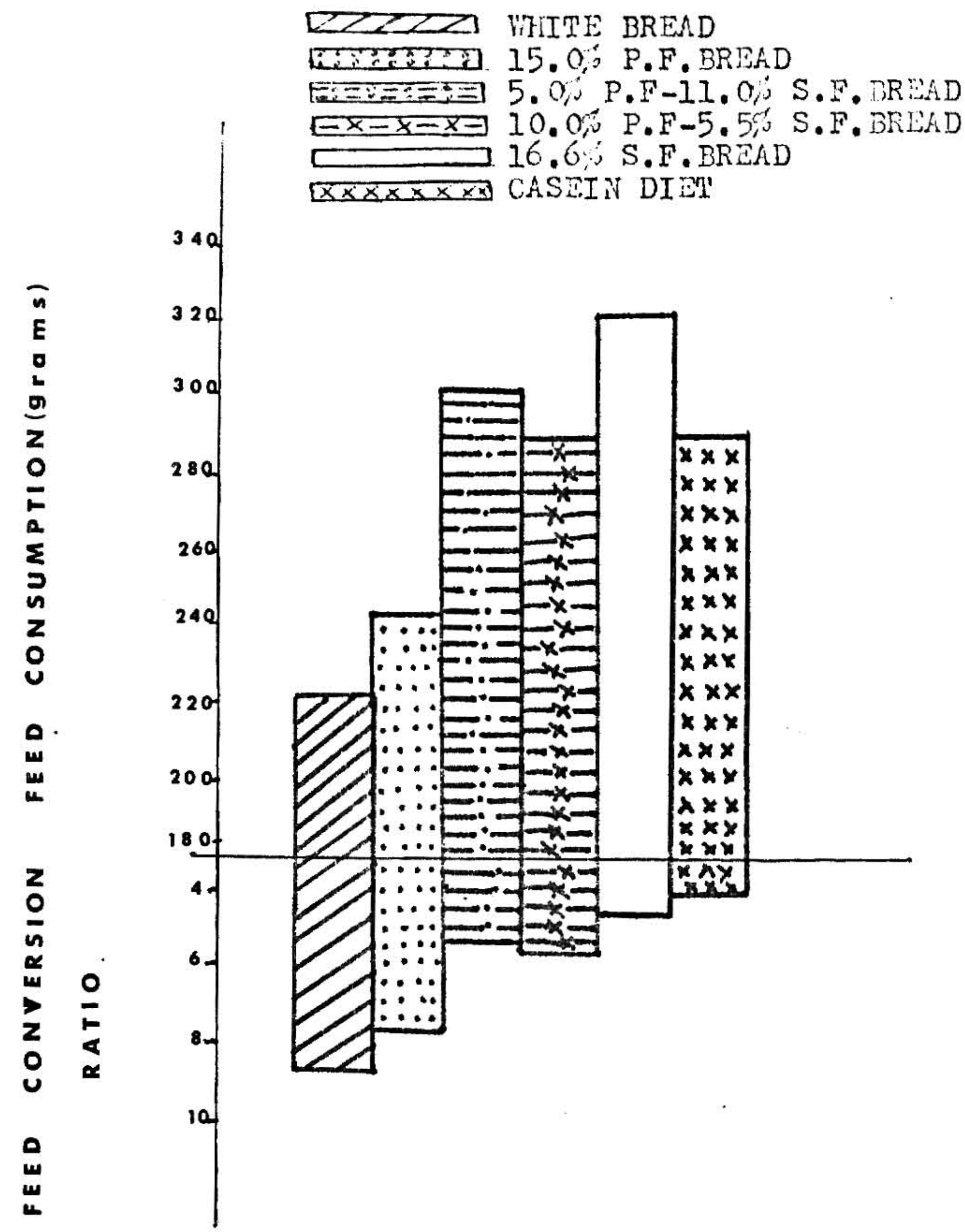

Fig.3. Average Feed Consumption and Feed Conversion of rats fed experimental diets.

TABLE 19. MEAN PERs OF THE SIX DIETS[a]

TREATMENT	WEIGHT GAIN (g.)	PROTEIN INTAKE (g.)	PER
White Bread	25.12	22.03	1.14
15.0% P.F. Bread	32.12	24.22	1.33
5.0% P.F-11.0% S.F Bread	56.87	30.00	1.89
10.0% P.F-5.5% S.F Bread	51.87	28.86	1.79
16.6% S.F Bread	69.00	32.06	2.15
Casein	71.87	29.03	2.47

Analysis of variance

Source	Sum of Squares	DF	Mean Square
Treatment	11.31	6	1.88
Error	3.94	49	0.88
Total	15.25	55	

[a]Eight rats per diet.

LSD:-Least Significant difference at the 5% level.

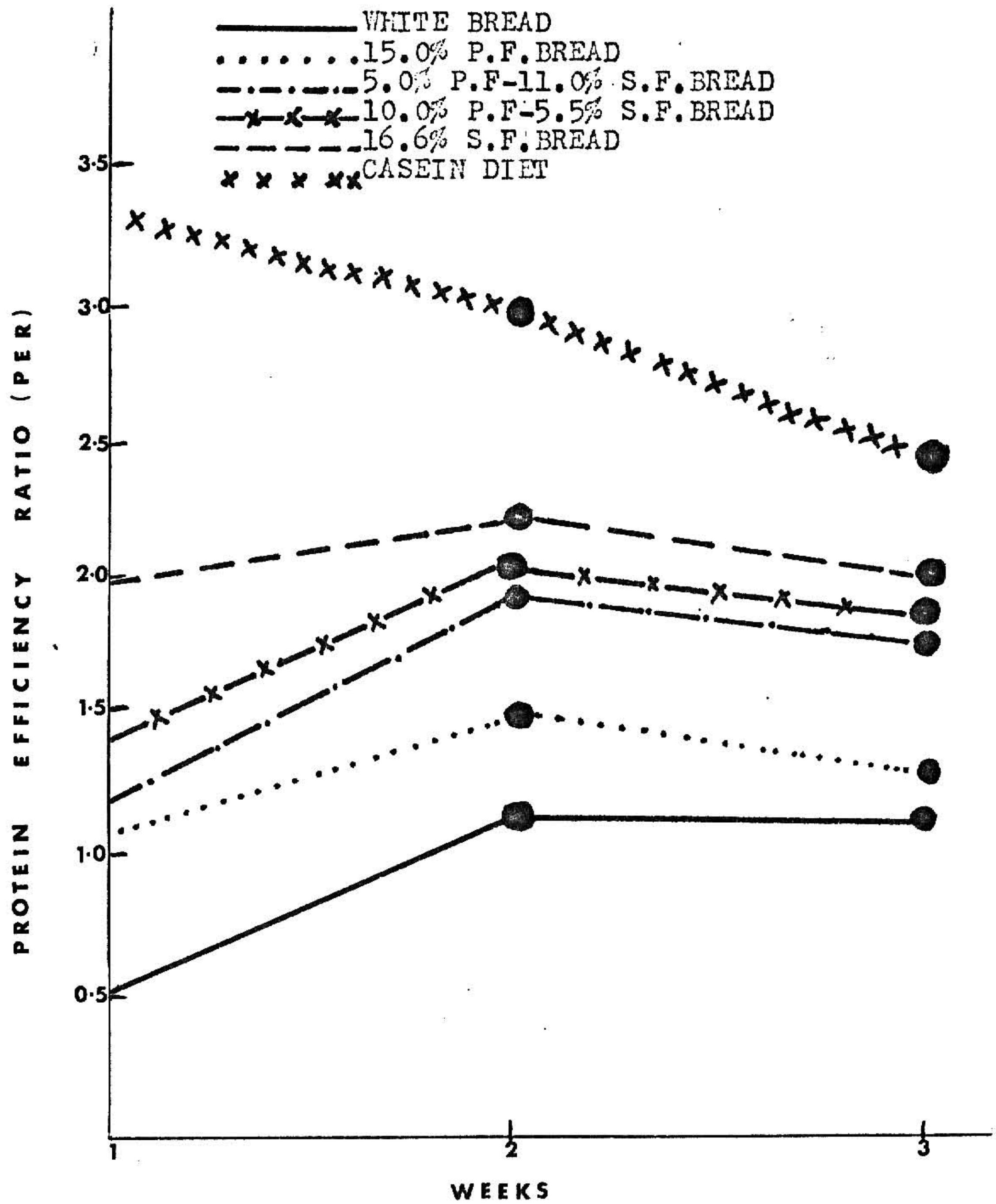

Fig. 4. Protein Efficiency Ratio for rats fed experimental diets.

gain (19). The main symptoms of lysine deficiency which occur with wheat proteins include cessation of growth, muscular wasting, hypoproteimia, anemia and reduction of calcification of bones (36, 34).

The amino acid profile of analyzed experimental breads (Table 15) and the results of rat growth studies were in agreement with this. Breads supplemented with soy flour had much higher values for lysine content. This resulted in the higher gains and PER values in 16.6% soy flour supplemented bread diet when compared to white flour and peanut flour breads.

White flour fortified with 15.0% peanut flour bread had a lysine content higher than white flour bread, but lower than 16.6% soy flour, 5.0% peanut-11.0% soy flour and 10.0% peanut-5.5% soy flour breads. This was reflected in the feeding trials by gains in body weight. Blends of peanut-soy flour breads had higher gains than those of 15.0% peanut and white flour breads. White flour fortified with 15.0% peanut flour bread had higher gains and PER values than that of white flour bread.

The results of nutritional study showed that nutritive value of the proteins of bread increases with supplementation with peanut flour and soy flour in the baking formula. This improvement of nutritive value can be attributed to the increased content of proteins, as well as that of lysine. Harris et al. (38) and Ehle and Jansen (48) have also observed improvement in the nutritive value of bread due to soy and peanut flour supplementation.

From this study showed that the 15.0% peanut flour fortified bread did not improve much weight gain and PER values, compared to soy flour, and blends of peanut-soy flour fortified breads, because peanut protein is deficient in methionine, lysine, isoleucine and threonine. When peanut flour was blended with soy flour, there was a much significant increase in weight gain and PER values, because soy protein contained more lysine, threonine, leucine, isoleucine and valine than peanut protein. So adding soy flour should improve the protein quality of peanut-fortified breads.

Feed Conversion:

Feed conversion ratios were shown in Table 16 and Fig. 3. Results indicated that rats fed casein diet and 16.6% soy flour supplemented bread converted more efficiently than rats fed other diets. These results were in agreement with protein efficiency ratios (PER). Typical rats were shown in Figs. 5, 6, 7, 8, 9, and 10.

From the results of this investigation, it is suggested that incorporation of peanut-soy flours to the white flour bread with SSL, to improve the baking performance and the nutritive value of the white bread.

Fig.5. Rat fed with wheat flour bread.

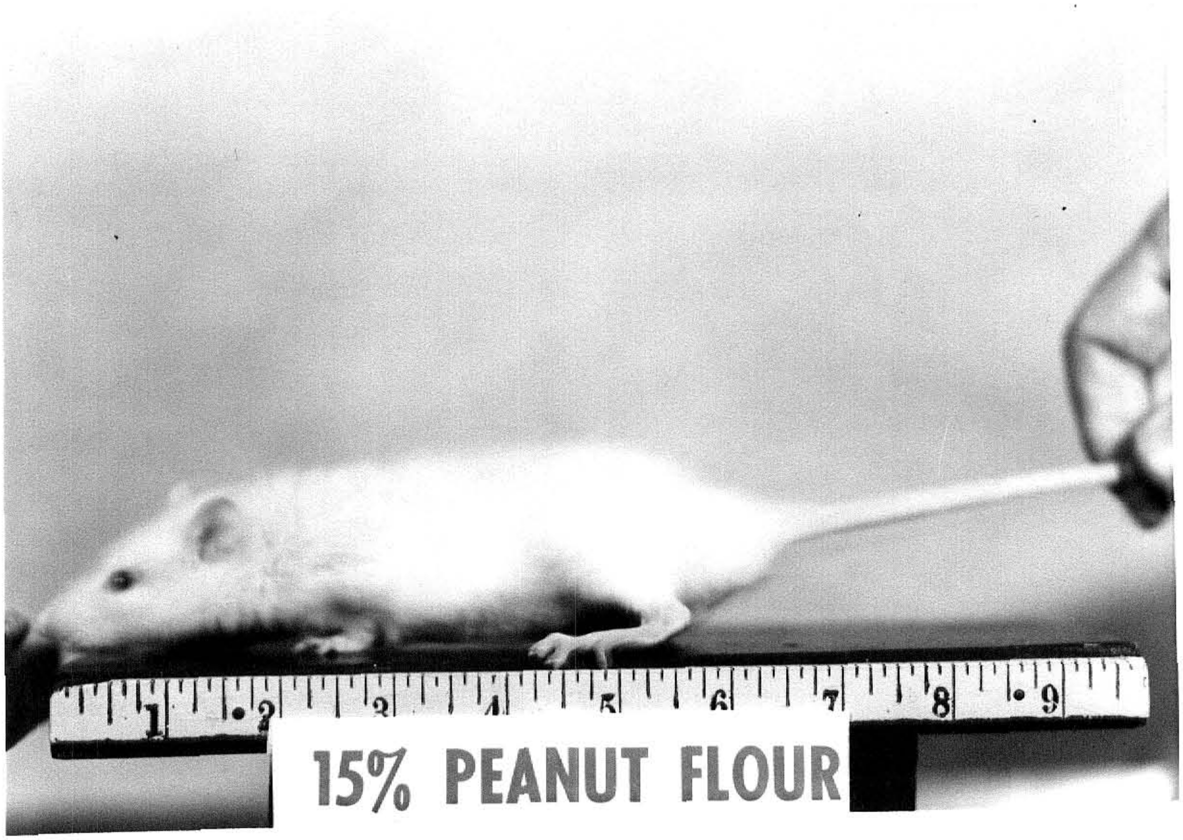

Fig.6. Rat fed with 15.0% peanut flour bread.

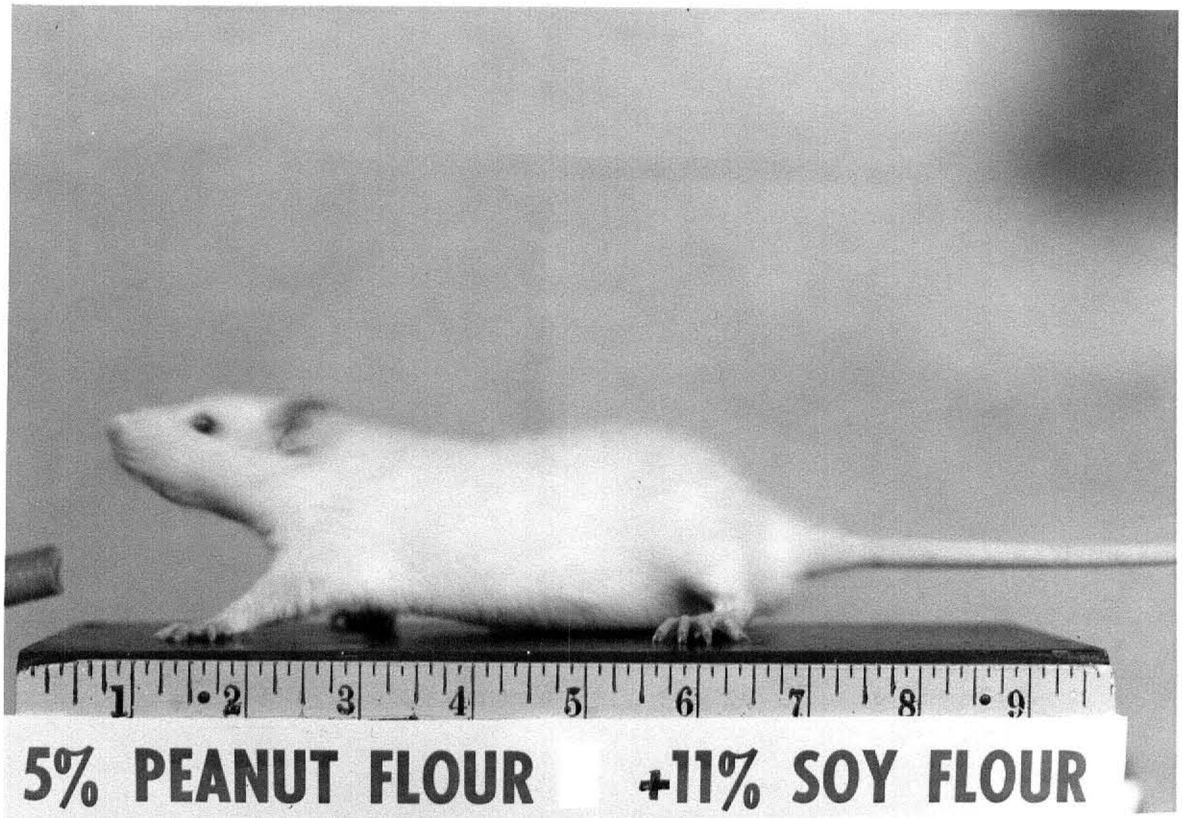

Fig. 7. Rat fed with 5.0% peanut flour-11.0% soy flour bread.

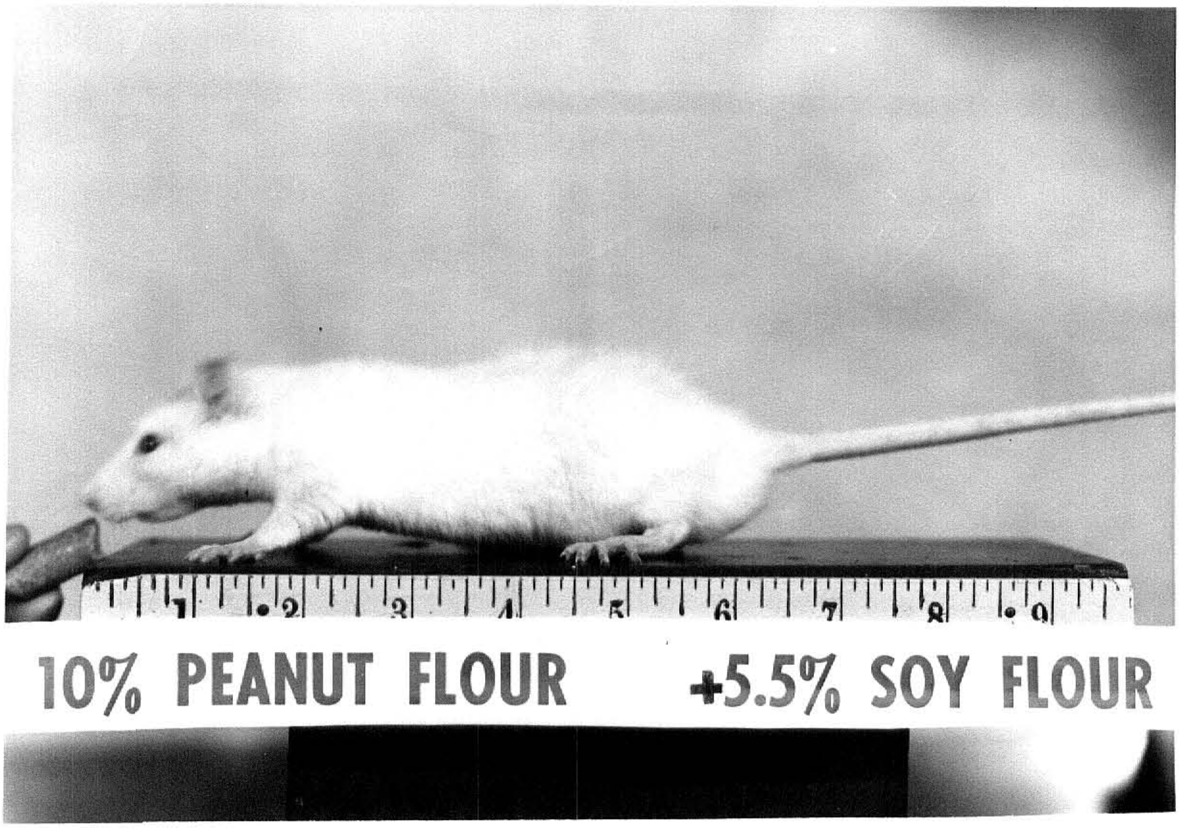

Fig. 8. Rat fed with 10.0% peanut flour-5.5% soy flour bread.

Fig.9. Rat fed with 16.6% soy flour bread.

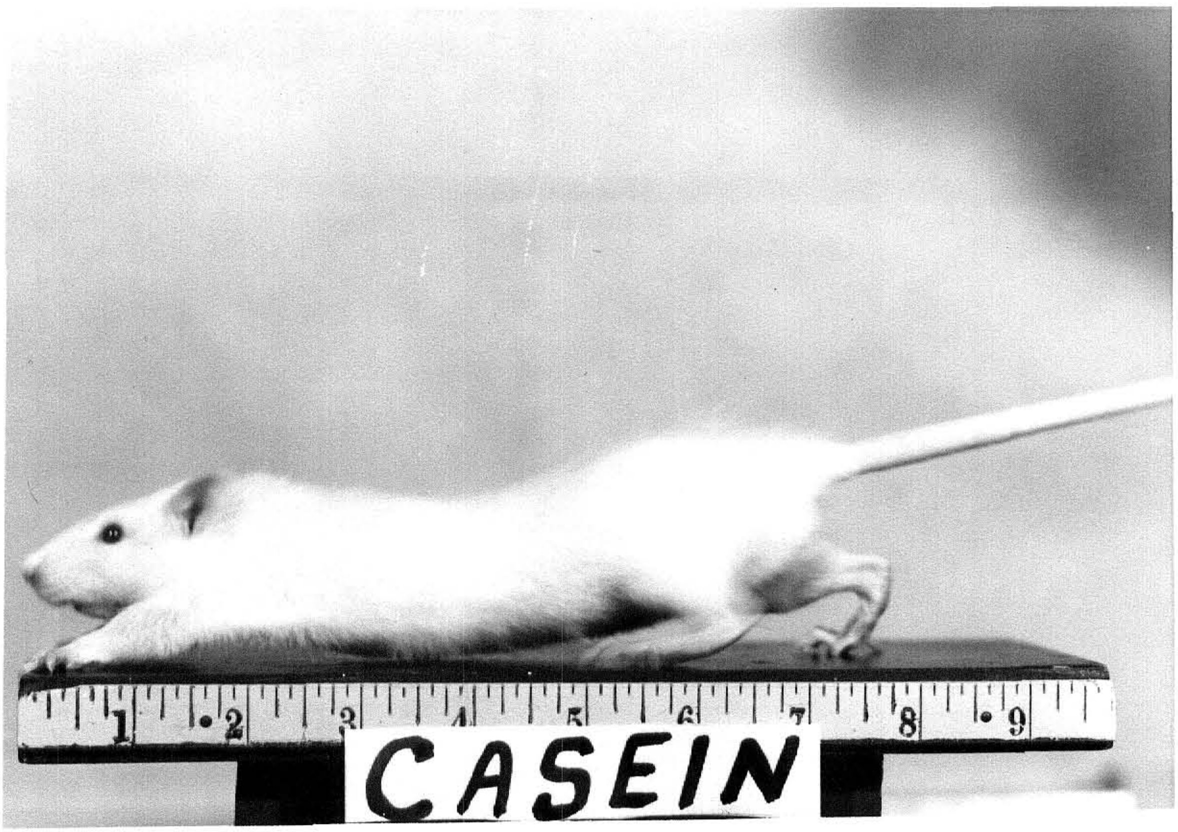

Fig.10. Rat fed with casein diet.

SUMMARY

This study was conducted to develop high-protein breads from wheat flour fortified with peanut flour or a blend of peanut-soy flours. Fortifying more than 10.0% peanut flour impaired dough property and baking quality of wheat flour. But dough conditioners, sodium stearoyl-2 lactylate, ethoxylated mono glycerides, or sucrose mono palmitate, all could counteract the adverse effects, so acceptable bread could be made with wheat flour fortified up to 15.0% peanut flour with the addition of one of the conditioners.

Wheat flour fortified with 15.0% peanut flour, with SSL, the specific loaf volume was 5.72 c.c/g, where as with SMP and EM were 5.65 and 6.00 c.c/g; without dough conditioners, the specific loaf volume of 15.0% peanut fortified bread was 4.71 c.c/g. Similar results were observed with peanut-soy flours blends of fortified breads. These results indicated that the addition of soy flour to peanut flour, reduced the specific loaf volume over 15.0% peanut flour fortified bread with SSL.

Peanut fortified bread with SSL, retained softness well during storage. The crumb of peanut fortified breads appeared much darker than other breads.

It is known that peanut protein is deficient in methionine, lysine, isoleucine, and threonine, its protein quality (amino acid pattern) could improved by fortifying with soy flour, as shown in this study. The breads made from wheat flour fortified with peanut, soy and blends of peanut-soy flours were biologically evaluated using casein as the standard

protein for comparison in rat growth studies, with cumulative weight gain and protein efficiency ratio as criteria for assessing protein quality. Statistical analysis showed significant ($P < 0.05$) improvement, for breads supplemented with 16.6% soy flour and peanut-soy flour blends; when measured by rate of growth and protein efficiency ratios. 15.0% peanut flour fortified bread showed higher improvement in growth and PER over white flour bread.

Rats fed with 16.6% soy flour bread had the highest cumulative weight gain than other diets. The PER value for 16.6% soy flour bread was the greatest, and PER values of peanut-soy flour blends were significantly ($P < 0.05$) higher than the 15.0% peanut and white flour breads. Fifteen percent peanut flour bread had higher PER value than white flour bread.

Rapid increase in world population, especially in the developing countries, peanuts are good source of protein, to eliminate the malnutrition in those countries.

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ACKNOWLEDGEMENT

The author treasures his sincere gratitude to Dr. Cho C. Tsen, major Professor, for his guidance and valuable suggestions during studies, research and preparation of this manuscript.

Special thanks to Dr. William J. Hoover, Head of the Department of Grain Science and Industry, for providing facilities, funds and materials needed to carry out this work and serving on supervisory committee and reviewing of this manuscript.

Special appreciation and thanks are due to Professor Arlin B. Ward, serving on supervisory committee and reviewing this manuscript.

Thanks are due to Dr. D. B. Parrish, for providing experimental facilities in animal studies; Dr. K. S. Reddy, for assistance, while baking breads and feeding animals.

Finally the author is grateful to his wife Usha, and his parents, brothers and sisters, for their encouragement, patience and understanding throughout the studies.

HIGH-PROTEIN BREADS FROM WHEAT FLOUR FORTIFIED WITH PEANUT FLOUR AND PEANUT-SOY BLENDS AND THEIR NUTRITIVE VALUES

by

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AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

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1975

ABSTRACT

The object of this investigation was to elucidate high-protein breads from wheat flour fortified with peanut flour, soy flour and a blend of peanut-soy flour. Fortifying more than 10.0% peanut flour or soy flour impaired dough property and baking quality of wheat flour. But sodium stearoyl-2 lactylate (SSL), ethoxylated mono glycerides (EM), or sucrose mono palmitate (SMP) counteracted the adverse effects, so acceptable bread could be made with wheat flour fortified with up to 15.0% peanut flour. In addition to raising the bread's protein content, its protein quality (amino acid pattern) could be improved by fortifying with peanut and soy flours. Peanut fortified bread retained softness well during storage. Its crumb appeared much darker than that of wheat flour bread.

Significant improvements in growth resulted from the use of bread supplemented with soy flour and a blend of peanut-soy flours, breads when measured by rate of growth and protein efficiency ratios. Breads made with 15.0% peanut flour, showed higher in growth over white flour bread.

Significantly higher weight gain and PER values were observed in 16.6% soy flour bread when compared to other supplemented diets. The PER and weight gains of both 5.0% peanut flour-11.0% soy flour and 10.0% peanut flour-5.5% soy flour breads have higher ($P < 0.05$) than those of the 15.0% peanut flour and white breads. Wheat flour fortified with 15.0% peanut flour bread had higher weight gain and PER values over white flour bread. The higher feed conversion was observed in 16.6% soy flour bread compared to other diets. These results were in agreement with protein efficiency ratios.

This study indicated that the high-protein breads from wheat flour fortified with peanut flour by using SSL, could improve the baking performances. This study also showed that the protein quality of white flour bread could be improved by the addition of peanut flour and a blend of peanut-soy flours, as judged from cumulative weight gain and PER results.