THE NUTRITIVE VALUE OF PEANUT MEAL, SOYBEAN MEAL AND VARIOUSLY PROCESSED FULL-FAT PEANUTS AND SOYBEANS AS SOURCES OF PROTEIN IN BROILER DIETS

by

ALFRED O. ADUKU

B. Sc., Ahmadu Bello University, Zaria, 1971

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Poultry Science

Department of Dairy and Poultry Science

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1973

Approved by:

Paul E. Sanford

Major Professor

THIS BOOK CONTAINS NUMEROUS PAGES WITH THE ORIGINAL PRINTING BEING SKEWED DIFFERENTLY FROM THE TOP OF THE PAGE TO THE BOTTOM.

THIS IS AS RECEIVED FROM THE CUSTOMER.

TABLE OF CONTENTS

INTRODUCTION

Most vegetable proteins are deficient in one or more amino acids which can be corrected by supplementing synthetic amino acids or by using two or more protein sources to supplement each other in poultry diets (Almquist, 1972).

In most practical diets, soybean oil meal which is complete in most nutritionally known amino acids except sulfur amino acids, is used as a protein supplement. In recent years, there has been much interest in feeding whole soybeans to poultry in order to utilize the protein and the oil (Nelson, 1970). Some countries have richer sources of vegetable oil than soybeans, and do not extract the oil before utilizing soybeans in poultry rations. Nigeria, for example, does not extract the oil from soybeans (18% oil) but from peanuts (50% oil). Practically all of Nigeria's soybeans are exported, and the soybean meal which is used in poultry feeding is imported. This increases the price of feeds which is a major cost in poultry production.

Soybeans are a relatively new crop in Nigeria, where production has been concentrated in the middle zone since about 1950. Production was 27,000 tons in 1963, all of which was exported because there was no taste or desire for it (F.A.O., 1966). There is great potential for increasing production since soybeans can be grown extensively from the southern part of Northern Nigeria to the south because its ecological requirements are similar to those of corn which is adapted to these areas (F.A.O., 1966).

The use of heat processed full-fat soybean to feed poultry or to correct the amino acid deficiencies in peanut meal could be considered as a means of lowering feed cost.

The study reported here involved the use of infrared cooked and ground soybeans, and extruded soybeans to supplement peanut meal, full-fat roasted and extruded peanut meal. The study further reexamined the use of these full-fat heat processed products and peanut meal as the main sources of protein in broiler diets.

REVIEW OF LITERATURE

Peanut meal is deficient primarily in methionine, lysine and possibly threonine (Grau, 1946). There is disagreement on the nature or order of the most limiting essential amino acids in peanut protein (Wessels, 1967). Fisher (1965) found the amount and availability of amino acids in peanut meals depend on processing, and the level of peanut protein used in the diet (Fisher, 1964). Grau (1946) found that methionine was the first limiting amino acid in peanut meal followed by lysine at dietary level of 20% protein. This finding is in agreement with the work of Anderson and Warnick (1965) at 18% protein, Wessels (1967) at 11% protein, Daghir et al. (1969) at 20% protein for chicks, and Pieterse (1963) at 10% protein for rats.

Fisher (1964) compared 12% protein and 24% protein and found that at 12% protein lysine, threonine and methionine were limiting in that order. At 24% protein level, lysine was first limiting followed by methionine, but threonine was not limiting at that level. This order of limiting amino acids agrees with the findings of Douglas and Harms (1959). Waldroup and Harms (1963) using a 32% protein diet found lysine, methionine and tryptophane limiting in that order. A good review of the amino acid deficiencies in peanut meal has been given by Anderson and Warnick (1965).

In roasted peanuts, lysine, threonine and methionine were limiting for rats (McOsker, 1962). In studies with chicks, Anantharaman and Carpenter (1965) found lysine, methionine and threonine limiting in that order in heated peanut flour. This was in agreement with the findings of Grau (1946) who used peanut meal.

Using mixtures of peanut meal (30%) and soybean meal (20%), Blaylock and Richardson (1950) found methionine to be the first limiting amino acid.

Attempts have been made to correct amino acid deficiencies of peanut meal by adding the limiting amino acids in concentrated form.

Grau (1946) used a 20% protein diet supplemented with 0.46% lysine, 0.2% and 0.4% D-L methionine and 0.5% threonine. Growth was decreased most by omission of methionine. A smaller but significant decrease was noted when lysine was omitted. Omission of tryptophane did not produce a significant reduction in growth rate. Grau (1946) concluded that peanut meal was lacking primarily in methionine, but was also slightly deficient in lysine.

Douglas and Harms (1959) supplemented peanut meal with 0.35% L-lysine, 0.3% methionine hydroxy analogue and 0.15% glycine and produced growth rate equal to that of feeding all soybean meal.

Blaylock and Richardson (1950) produced a rate of growth in chicks equal to that obtained with soybean meal when a 20% protein peanut meal diet was supplemented with 0.3% D-L methionine and 0.2% L-lysine. When higher levels of 0.6% D-L methionine and 0.4% L-lysine were added, the chicks were slightly heavier, but the weights were not significantly different from those obtained with smaller amounts of lysine and methionine.

Waldroup and Harms (1963) used 0.3% lysine, 0.3% D-L methionine and 0.10% tryptophane in a 22% protein diet, and found no significant difference in weights of chicks from the soybean meal control diet, but the performance on peanut meal diet was below those of soybean meal.

At a much higher level of a 24% protein peanut meal diet, Fisher (1964) supplemented 0.4% lysine and 0.3% D-L methionine and obtained weights which were generally equivalent to those obtained with high-quality proteins such as fish meal. Fisher (1965) recommended the addition of 0.2% threonine.

The various levels of amino acids thus supplemented could be associated with the various percentages of peanut meal protein in the diet. Almquist (1972) indicated that as the gross protein level is raised, the percentage of essential amino acid required may decrease. This would mean that a higher level of amino acid supplementation would correspond with a higher peanut protein in the diet.

Except for sulfur containing amino acids and lysine, it is too expensive to add the missing amino acids in concentrated form in practical nutrition (Almquist, 1972). A more practical method of balancing amino acid deficiencies in a diet is to choose a combination of proteins so that deficiencies of one protein will be compensated for by an abundance of certain required amino acids in other proteins. To accomplish this soybean protein has been used as a protein supplement.

It is known from analysis and experiments that soybean protein is complete in essential amino acids except for the sulfur-amino acids (Almquist, 1972; Warnick and Anderson, 1968).

Douglas and Harms (1959), Driggers and Tarver (1958) have a good review of the supplementary effects of soybean meal on peanut meal with satisfactory results.

Douglas and Harms (1959) found that when 50% of soybean meal was replaced with peanut meal, a significant reduction in growth rate of chicks occurred. Addition of 0.15% L-lysine, 0.2% methionine hydroxy analogue and 0.15% glycine produced growth rate equal to that obtained from feeding all soybean meal.

Driggers and Tarver (1958) obtained results equal to that of soybean meal when peanut oil meal replaced one-half the soybean oil meal. (The diet included 3% of a fish solubles blend.) They indicated that fish meal with condensed fish solubles added appeared to be a good supplementary source of lysine.

Altschul et al. (1948) found 5.5% of peanut meal could satisfactorily replace an equal amount of soybean meal.

Heuser et al. (1946) also indicated that peanut meal satisfactorily replaced half of the soybean protein when the diet contained 20% protein and 3% fish meal. The level of peanut meal in the diet was 15%. This level was also found to be satisfactory by Hammond (1944).

In areas where soybeans are not processed, unextracted soybeans have a greater nutritional value as a main source of protein or as a supplement to peanut meal or unextracted peanut meal. Unextracted soybeans are an excellent source of protein since they are complete in amino acids except sulfur-containing amino acids (Almquist, 1972). Soybeans are high in polyunsaturated vegetable fats which are an excellent source of metabolizable energy and linoleic acid (Carew et al., 1959; Scott et al., 1969; Waibel, 1972).

Raw soybeans need to be subjected to two types of treatment to be comparable nutritionally to soybean meal. These are heat treatment, and mechanical pressure to cause cellular disruption of the cell walls to allow proper digestion (Nesheim, 1961; Nelson, 1970; Carew et al., 1961; Carew et al., 1962).

Detrimental effects of raw soybeans are ascribed to their heat labile toxic factors, notably trypsin inhibitors and hemaglutinins (Coates _et al._, 1970; Nelson, 1970; Hains and Lyman, 1961). Wood _et al._ (1971) called the toxic factor soyin. Enlarged pancreas and depressed growth were demonstrated. The mechanism of growth retardation has been explained by many workers. Hains and Lyman (1961) associated growth depression with restricted feed intake and trypsin inhibitor, soyin, which stimulates the pancreas to secrete large quantities of enzyme protein which are ultimately lost to the animal. Contrary but direct evidence was given by Lepkovsky _et al._ (1971). They found that raw soybean diets have a lower nutritional value than heated soybean diets, because raw soybean trypsin inhibitors impair proteolysis, not by decreasing the activities of protease in the intestine, but rather by their action on intestinal proteins causing the formation of trypsin inhibitor-protein complexes which resist proteolysis even in the presence of high concentrations of proteases. These complexes are lost in feces.

A similar result was found by Bouthilet _et al._ (1950) who used colostomized chickens. A methionine-rich complex was detected in the feces of chickens fed raw soybeans. High nitrogen and methionine values in feces indicated poor digestibility. This concurs with the findings of Hayward and Hafner (1940) that raw soybeans are deficient in methionine and cystine.

Using free amino acids values as good indication of digestibility of dietary protein, Bielorai _et al._ (1972) found that free amino acid levels of the intestinal contents were higher for heated soybean than for raw soybeans at both 15% and 22% protein level in the diet.

A similar heat labile, anti-tryptic factor has been found in raw peanuts. Bielorai (1969) found that raw peanut meal fed to chicks produced growth retardation, pancreas hypertrophy, but to a lesser extent than raw soybeans. He indicated that amino acid imbalance and anti-tryptic activity are problems of raw peanut meals.

Many workers agree that trypsin inhibitor is heat labile. Bouthilet et al. (1950) showed that heat treatment above 100°C was necessary to destroy trypsin inhibitor. Hayward and Hafner (1940) found that heating was equivalent to supplementing cystine and methionine. A good review of the effect of heating temperatures and duration of heating on raw peanuts has been given by Anantharaman and Carpenter (1965, 1969), Neuccere et al. (1972), and McOsker (1962).

For raw soybeans, the various temperatures and periods of heating used to destroy the trypsin inhibitor has been shown by Mustakas and Griffin (1964); Hayward et al. (1937); Runnels (1961); Featherston and Rogler (1966); and Renner and Hill (1960).

Most of these workers agree with Bouthilet et al. (1950) that a temperature of over 100°C (212°F) is necessary to destroy the trypsin inhibitor. Mustakas and Griffin (1964) reported that a temperature range of 240-250°F (128-138°C) was adequate to remove trypsin inhibitor.

Mechanical pressure on the beans will cause cellular disruption allowing proper digestion of soybean oil by chickens (Nesheim, 1961).

Oil in heated, ground soybeans was poorly absorbed because of less cellular destruction (Carew et al., 1962; Nesheim, 1961). Tian et al. (1970) fed turkey poults infrared cooked and ground soybean and 44% protein soybean meal and found that poults fed infrared cooked soybeans had a slower growth rate and slightly reduced feed efficiency compared to those fed soybean meal. This was further confirmed by White et al. (1967), Hull *et al*. (1968), and Mitchell *et al*. (1972), who found that diets containing infrared cooked and ground beans were inferior to diets containing solvent extracted soybean meal, but of equal value when fed to chicks in pellet form. The improvement due to pelleting was associated with the sheer force in pelleting causing cellular disruption. Heat treatment during the pelleting process can improve the nutritional value of slightly underheated beans (Carew and Nesheim, 1962). They did not find beneficial effect of pelleting from properly heated ground soybeans.

Mitchell *et al*. (1972) found that finely ground soybeans were significantly better than coarsely ground beans. The percent digestibility increased from approximately 55% in coarsely ground beans to 90% in finely ground beans.

Hull *et al*. (1968) suggested the lower fat digestibility resulted when infrared cooked beans were cooked whole and then reground through a 1/32 inch screen, thus the cell rupture was probably not as complete as in the extruded soybeans. They postulated that flaking infrared cooked soybeans rather than grinding would increase the nutritional value of roasted soybeans by causing greater cellular rupture.

Heat treated and flaked soybeans stimulated growth equal to soybean meal with soybean oil added because of cellular disrupture (Carew *et al*., 1959; Nesheim, 1961; Carew *et al*., 1962; Featherston and Rogler, 1966).

Extruded unextracted soybeans supported chick performance equal or superior to soybean meal with oil added (Hull *et al*., 1968; Mustakas and Griffin, 1964; Carew and Nesheim, 1962).

Sloan *et al*. (1971) found that performance of extruded soybeans did not equal that of solvent extracted soybean meal. These results were supported by Wood et al. (1971), White et al. (1967) that efficiency of nitrogen and energy utilization were slightly lower in extruded soybeans than the control diet. They suggested that heat treatment during extrusion process was insufficient to reduce completely the anti-tryptic factors to innocous levels.

Waibel (1972) summarizing all the various heat treatments for soybeans reported that all heat treated soybeans depressed growth at four weeks of age, after which growth recovery was noted.

MATERIALS AND METHODS

Raw, full-fat soybeans and peanuts were ground and extruded using a Wenger X-25 extruder at 250°F (121°C) at the Department of Grain Science and Industry, Kansas State University. The extruded products were spread on concrete floor to cool and dry. The complete process is reported by Wood et al. (1971).

Roasting of full-fat soybeans and peanuts was done at Frankfort, Kansas which is 50 miles northeast of Manhattan. A gas-fired Roast-a-Tron which emits infrared heat was used. A temperature of 122°C to 125°C was used. The hot roasted beans were spread out to cool, then ground through a 3/32 inch diameter screen using a hammer mill at the Kansas State University Small Animal Research Laboratory. Peanuts were ground through a 3/16 inch screen as they clogged the 3/32 inch screen. A complete infrared processing condition is described by White et al. (1967).

Diets containing the heat processed products were mixed at the Kansas State University Poultry Research Center. The main ingredients were weighed in pounds on a large platform balance, whereas the microingredients were weighed in grams on a double pan computagram balance. The microingredients were premixed with yellow corn for 5 minutes in a small electrical Hobart mixer. The premix was added to the remaining amount of 100 pounds of macro ingredients in a 100-pound horizontal mixer. Mixing continued for 5 minutes. Ten isonitrogeneous diets of 24% protein (starter) and 20% protein (finisher) were mixed. One diet was the K.S.U. corn-soybean meal control diet (Tables A-1 to A-2).

The diets were placed in labeled paper bags and stored in the Nutrition Laboratory. The feed was weighed out in kilograms into previously weighed cans. At the end of each two-week period, feed remaining in the feeders and diet storage cans were weighed back, and this amount was subtracted from the total feed weighed out to give the amount of feed consumed in kilograms.

Day-old meat-strain broiler-type male chickens were randomized into 30 lots of 10 chicks per lot making a total of 300 chicks for each experiment. The lots were randomly assigned to cage tiers. The chicks were wing banded, weighed and placed in electrically heated brooder batteries with wire floors for 4 weeks. The chicks were transferred at 4 weeks of age to unheated finisher batteries for the last 4 weeks of the experiment.

Feed and water were supplied *ad libitum*. The room temperature was kept at about 70°F. Every two-week period birds were weighed individually in grams and the feed was weighed back. Hence body weight-gain and feed consumed were determined. Feed utilization was determined by dividing feed consumed by weight gain for that period (Tables A-4 to A-17).

The data were analyzed using one way analysis of variance in testing for significant difference between treatment means for weight gain and feed utilization as described by Snedecor and Cochran (1971).

The above procedure was repeated for experiment II, but with a difference in that amino acids were added to diets 2, 4, 6, 7 and 9. The complete diets 7, 9 and 10 containing full-fat peanuts were extruded before adding amino acids and vitamins. This was due to the difficulty of extruding full-fat peanuts in experiment I.

RESULTS AND DISCUSSION

Weight gains and feed utilization of treatment groups were used as the criteria for evaluating the experimental diets as compared with the soybean meal control diet.

Experiment I

Weight gain: The chicks fed diet 10 containing extruded full-fat soybean and peanuts gained significantly better than the soybean meal control diet (no. 1) as shown in Table 1 and Tables A-8 to A-10. Diet 3 containing roasted and ground full-fat soybeans gained better than the control diet, but there was no significant difference between them from 2-8 weeks ($P > .05$). There was no significant difference between diet 5 containing extruded soybeans, diet 8 containing infrared roasted and ground full-fat soybeans and peanuts and the control diet at 0-4, 0-8 weeks as shown in Tables A-8 and A-10.

Diets 4, 6 and 9 were not significantly different from one another in weight gain at 8 weeks (Table 1 and Table A-10), but they were significantly poorer than the control diet at ($P < .05$) level.

Diet 7 containing infrared roasted and ground full-fat peanuts, and diet 2 containing peanut meal as the main source of protein were significantly poorer than all other diets ($P < .05$) (Table 1).

Table 1. Analysis of variance of average weight gain in experiment I

		Mean Squares						
Source	d.f.	0-2	2-4	4-6	6-8	0-4	0-6	0-8
Treatment	9	7840.644^{**}	31729.6562^{**}	60044.914^{**}	38325.281^{**}	70222.000^{**}	249477.437^{**}	468984.0625^{**}
Error	20	93.9531	1790.8750	1872.474	3701.225	2026.959	2769.300	9498.148

	Means-Weight Gain (grams)						
Treatment	0-2	2-4	4-6	6-8	0-4	0-6	0-8
1	178.367^{c}	416.366^{b}	595.166^{a}	624.867^{a}	594.733^{b}	1189.866^{ab}	1814.767^{b}
2	63.400^{f}	124.967^{d}	232.039^{c}	322.010^{c}	188.367^{f}	420.410^{e}	742.416^{e}
3	218.200^{b}	434.833^{ab}	619.266^{a}	576.566^{a}	653.003^{b}	1272.300^{a}	1848.866^{ab}
4	148.900^{d}	350.433^{bc}	483.733^{ab}	567.600^{a}	499.333^{c}	983.066^{c}	1550.667^{c}
5	184.733^{c}	403.066^{b}	563.266^{a}	615.233^{a}	587.800^{b}	1151.066^{b}	1766.300^{b}
6	143.000^{d}	331.866^{bc}	485.100^{ab}	532.533^{a}	474.866^{cd}	959.966^{c}	1492.500^{c}
7	108.433^{e}	269.533^{bc}	236.100^{c}	349.233^{c}	377.967^{e}	614.066^{d}	981.066^{d}
8	174.667^{c}	397.200^{b}	546.433^{a}	609.400^{a}	571.866^{bc}	1118.300^{b}	1727.700^{b}
9	151.933^{d}	367.466^{b}	469.500^{b}	511.100^{ab}	519.400^{bc}	988.900^{c}	1500.000^{c}
10	240.733^{a}	497.00^{a}	603.133^{a}	643.100^{a}	737.900^{a}	1340.866^{a}	1983.967^{a}

**Significant ($P < .01$).

Means with the same letter are not statistically different at 5% level of probability.

Table 2. Analysis of variance of average feed utilization, experiment I.

Sources	d.f.	Mean Squares 0-2	2-4	4-6	6-8	0-4	0-6	0-8
Treatments	9	0.394^{**}	0.793^{**}	0.285^{ns}	0.087^{ns}	0.644^{**}	0.354^{**}	0.200^{**}
Error	20	0.019	0.072	0.207	0.064	0.048	0.0212	0.023

Treatments	Means-Feed Utilization (kg feed per kg gain) 0-2	2-4	4-6	6-8	0-4	0-6	0-8
1	1.573^{b}	1.957^{b}	2.290^{a}	2.593^{a}	1.840^{b}	2.020^{b}	2.267^{b}
2	2.540^{c}	3.223^{c}	2.693^{a}	2.483^{a}	2.990^{c}	2.823^{c}	2.677^{c}
3	1.377^{a}	1.720^{ab}	1.940^{a}	2.577^{a}	1.603^{a}	1.767^{a}	2.020^{b}
4	1.647^{b}	1.990^{b}	2.207^{a}	2.677^{a}	1.887^{b}	2.043^{b}	2.277^{b}
5	1.587^{b}	1.757	2.137^{a}	2.427^{a}	1.703^{ab}	1.917^{ab}	2.093^{b}
6	1.757^{b}	2.110^{b}	2.330^{a}	2.650^{a}	2.003^{b}	2.170^{b}	2.330^{b}
7	1.433^{ab}	1.417^{a}	2.767^{a}	2.313^{a}	1.380^{a}	1.740^{a}	1.903^{a}
8	1.360^{a}	1.577^{a}	1.877^{a}	2.170^{a}	1.507^{a}	1.690^{a}	1.860^{a}
9	1.327^{a}	1.553^{a}	1.947^{a}	2.350^{a}	1.490^{a}	1.707^{a}	1.920^{a}
10	1.350^{a}	1.653^{ab}	2.027^{a}	2.297^{a}	1.553^{a}	1.763^{a}	1.930^{a}

ns = nonsignificant. **Significant ($P < .01$).

Means with the same letter are not statistically different.

Feed utilization: During periods 4-6 weeks and 6-8 weeks, there were no significant differences between all the experimental diets and the soybean meal control diet in feed utilization ($P > .05$) (Table 2). During other periods, diets 5, 3, 9, 10, 7 and 8 were equal or better than the control diet (Table 2). Diets 4 and 6 were not significantly different from the control diet but were slightly poorer than the control diet. Diet 2 containing peanut meal was significantly poorer than the control diet (Table 2).

Peanut meal as the sole source of protein, diet 2, was deficient in lysine and methionine, lysine being the most limiting (Table A-3). This was also confirmed by Fisher (1964) using 24% protein diet, and Douglas and Harms (1959). This would account for the poor weight gains, poor feathering and feed utilization.

Diets 7 and 9 containing full-fat peanuts were limiting in lysine, methionine and threonine in that order (Table A-3). This corresponds with the finding of Anantharaman and Carpenter (1965). The extruded diet 9 was significantly better in weight gain than the roasted and ground peanuts in diet 7 (Table A-10), but the two diets were not significantly different in feed utilization. Both diets contained 38.52% fat by calculation (Table A-3). This level of fat was too high for a practical ration as manifested by clogging of the hammer mill and the extruder die. It was difficult to mix with minerals and vitamins as it was sticky and oily. It was easily compacted and baby chicks had difficulty in eating it.

In diet 8, the complete diet had to be ground as the peanut component alone would clog the hammer mill. Diet 10 had to be extruded as a complete diet for the same reason.

When one-half of soybean protein was replaced with one-half of peanut meal protein in diets 4 and 6 (Table A-1) deficiency of lysine was created at 0.04% in each diet (Table A-3). These diets were not significantly better than each other although diet 4 containing roasted and ground soybean was better in both weight gains and feed utilization (Tables A-7 to A-10). The poorer feed utilization and weight gain of diet 6 containing some extruded soybeans was in part attributed to possible underheating which may not have completely destroyed the trypsin inhibitor (Wood et al., 1971; White et al., 1967).

When one-half of full-fat soybean protein was replaced with one-half of full-fat peanut protein (Table 1) diets 8 and 10 were adequate in lysine and methionine as shown in Table A-3. Birds fed diet 10 gained significantly better than the control diet at 8 weeks as shown in Table A-10. There was no significant difference in weight gain between the control diet and diet 8. The significant difference in weight gain in diet 10 over diet 8 was associated with extrusion processing which made the nutrients more available (Nesheim, 1961), however, there was no significant difference between them in feed utilization.

Full-fat soybean as a sole source of protein in diets 3 and 5 were not significantly different from each other in feed utilization and weight gained at 8 weeks (Table A-10), but diet 3 was better than diet 5 which was extruded. This was attributed to underheating of the extruded beans due to extrusion processing (Wood et al., 1971; White et al., 1967).

For weight gain and feed utilization, diets 10, 8, 3, and 5 were equal or better than the soybean meal control diet. These diets were adequate in amino acid content and were relatively high in energy due to higher fat content (Table A-3).

Experiment II

Weight gains: There was no significant difference between diets 1, 2, 3, 4, 9 and the control diet at 8 weeks as shown in Tables 3 and A-17.

Diet 2 containing peanut meal as sole source of protein was supplemented with 0.3% L-lysine and 0.06% D-L methionine (Table 5) and produced weight gain which was not significantly different from the soybean meal control diet at 8 weeks (Table 3). This result is in agreement with the finding of Blaylock and Richardson (1950), Douglas and Harms (1959), Waldroup and Harms (1963), and Fisher (1964). The level of lysine supplemented in this experiment at 0.3% L-lysine was also used by Waldroup and Harms (1963), but their levels of methionine supplement was different at 0.3%.

Diet 4 containing half peanut meal protein and half infrared roasted and ground soybean protein was supplemented with 0.04% L-lysine and produced weight gain which was not significantly different from the control diet ($P > .05$) (Table 3). Diet 6 which contained similar ingredients as diet 4 but contained extruded soybean, produced weight gain which was significantly poorer than the control diet (Table 3). Diet 6 was not significantly different from diet 4, although diet 4 was slightly better (Table A-17). This was explained as inadequate heat treatment during the extrusion (Wood et al., 1971; White et al., 1967).

Similar effects of inadequate heat treatment may explain the poor weight gain in diets 5 and 10 (Table A-17). A urease test detected large amounts of ammonia which was indicative of underheating of the extruded products and confirmed that the trypsin inhibitor was not reduced to harmless levels.

Table 3. Analysis of variance of average weight gain, experiment II.

		Mean Squares						
Sources	d.f.	0-2	2-4	4-6	6-8	0-4	0-6	0-8
Treatment	9	7655.082**	46996.664**	43880.394**	44509.582	90428.187**	253032.062**	496009.062**
Error	20	198.006	307.834	1768.990	573.831	828.340	3362.050	3572.550

	Means-Weight Gain (grams)						
Treatment	0-2	2-4	4-6	6-8	0-4	0-6	0-8
1	197.167^{a}	432.066^{a}	526.667^{a}	565.000^{ab}	629.233^{a}	1155.900^{a}	1720.900^{a}
2	131.900^{b}	400.366^{ab}	521.400^{a}	607.700^{a}	532.266^{b}	1053.666^{ab}	1661.366^{a}
3	190.467^{a}	437.766^{a}	502.467^{a}	579.066^{a}	628.233^{a}	1130.700^{a}	1709.800^{a}
4	180.033^{a}	428.233^{a}	483.167^{a}	526.166^{b}	611.267^{a}	1094.433^{a}	1620.600^{a}
5	140.933^{b}	358.800^{bc}	448.633^{ab}	591.533^{a}	499.733^{b}	948.367^{b}	1539.900^{ab}
6	145.667^{b}	379.333^{b}	459.767^{a}	545.433^{ab}	525.000^{b}	984.767^{b}	1530.200^{ab}
7	25.467^{e}	33.500^{e}	138.500^{d}	216.633^{d}	58.967^{e}	197.467^{d}	414.100^{d}
8	95.833^{d}	220.067^{d}	332.333^{c}	416.566^{c}	315.900^{d}	648.233^{c}	1064.800^{c}
9	120.667^{bc}	375.967^{b}	515.833^{a}	616.867^{a}	496.633^{b}	1012.466^{ab}	1629.333^{a}
10	123.567^{b}	337.333^{c}	495.567^{a}	570.333^{ab}	460.900^{bc}	956.466^{b}	1526.800^{b}

**Significant ($P < .01$).

Means with same letter are not statistically different at 5% level of probability.

Table 4. Analysis of variance of average feed utilization, experiment II.

Source	d.f.	Mean Squares 0-2	2-4	4-6	6-8	0-4	0-6	0-8
Treatments	9	2.786^{**}	2.360^{**}	0.512^{**}	0.378^{**}	2.487^{**}	0.210^{**}	0.142^{**}
Error	20	0.235	0.745	0.035	0.042	0.456	0.053	0.024

Means-Feed utilization (kg feed per kg gain)

Treatments	0-2	2-4	4-6	6-8	0-4	0-6	0-8
1	1.573^{a}	1.987^{a}	2.463^{b}	2.303^{c}	1.857^{a}	2.130^{b}	2.317^{b}
2	1.767^{a}	1.850^{a}	2.303^{b}	2.167^{ab}	1.853^{a}	2.060^{b}	2.100^{b}
3	1.500^{a}	1.763^{a}	2.533^{b}	2.620^{c}	1.680^{a}	2.053^{b}	2.247^{b}
4	1.650^{a}	1.863^{a}	2.597^{b}	2.700^{c}	1.800^{a}	2.150^{b}	2.330^{b}
5	1.887^{a}	1.943^{a}	2.620^{b}	2.430^{c}	1.930^{a}	2.253^{b}	2.313^{b}
6	1.733^{a}	1.903^{a}	2.650^{b}	2.693^{c}	1.877^{a}	2.237^{b}	2.400^{bc}
7	4.750^{b}	4.533^{b}	1.613^{a}	1.720^{a}	4.617^{b}	2.437^{b}	2.083^{b}
8	1.990^{a}	2.037^{a}	2.483^{b}	2.070^{ab}	2.020^{a}	2.253^{b}	2.183^{b}
9	1.793^{a}	1.293^{a}	1.577^{a}	1.923^{a}	1.400^{a}	1.493^{a}	1.657^{a}
10	1.730^{a}	1.657^{a}	1.957^{ab}	2.343^{bc}	1.680^{a}	1.820^{ab}	2.017^{b}

**Significant ($P < .01$).

Means with same letter are not statistically different at 5% level of probability.

Table 5. Average weight gains and feed utilization due to soybean and amino acid supplementation.

	Diet	Weight Gain in Grams	Kg Feed per Kg Gains
1	K.S.U. soybean meal control[1]	1767.83	2.19
2	All peanut meal	772.97	2.75
2[a]	No. 2, + 0.3% lysine, 0.06 D-L methionine	1661.37	2.10
3	Roasted, ground soybean[1]	1779.33	2.13
4	1/2 Peanut meal + 1/2 soybean, ground	1550.67	2.28
4[a]	No. 4, + 0.04% lysine	1620.60	2.33
5	Extruded soybean[1]	1653.10	2.20
6	1/2 Peanut meal + 1/2 soybean extruded	1492.50	2.33
6[a]	No. 6, + 0.04% lysine	1530.20	2.40
7	Roasted, ground peanut	981.01	1.90
7[a]	No. 7, + 0.25% lysine, 0.20% D-L methionine	414.10[2]	2.08
8	1/2 Roasted ground peanut + 1/2 extruded soybean[1]	1727.70	1.86
9	Extruded peanut	1454.33	1.99
9[a]	No. 9, + 0.25% lysine, 0.20% D-L methionine	1629.33	1.66
10	1/2 Extruded peanut + 1/2 extruded soybean[1]	1755.38	1.97

[a]Indicates amino acid supplementation.

[1]Averages of experiments I and II where amino acids were not supplemented.

[2]Seriously burned peanuts, effect of amino acid supplementation is shown in 9[a].

Diet 7 which contained all full-fat infrared roasted and ground peanuts as a sole source of protein was supplemented with 0.25% L-lysine and 0.2% D-L methionine (Table 5). The response to this supplementation was poor due to overheating. The peanuts were roasted in winter time off campus and were returned in burlap sacks. The heat retained in the sacks in transit caused overheating (browning) of soybeans and caramelization of peanuts. The charring of peanuts could be attributed to its high fat content which increased the heat. Anantharaman and Carpenter (1965) found that severely heated peanuts supported poorer growth and showed greatest damage to lysine.

Diet 9 contained similar ingredients and amino acid supplementation as diet 7 but the peanuts in diet 9 were extruded. This diet was not significantly different from the control diet at 8 weeks ($P > .05$) (Table 3). This diet had a fat level of 38.52% by calculation and calorie:protein ratio of 79:1 (Table A-3). The good weight gain response to this high fat diet was not in agreement with the finding of Scott _et al_. (1969) that excess energy caused a decrease in growth rate due to excess dietary energy levels causing low feed intake below that needed for optimum growth or production. The problems of the high fat diets were difficulty in grinding, extruding, mixing due to sticking, oxidative rancidity and loss of energy in the form of oil in paper bags. It seems obvious that if the amino acids of a diet high in fat are adequate, the feed would stimulate good growth rate.

Diet 8 which contained half infrared roasted and ground soybean protein and half peanut protein was also overheated. The peanut component was partially charred. The soybean portion was overheated but not charred. Clandinin _et al_. (1947), Westfall and Hauge (1948) reported that overheated soybean was deficient in known vitamins, available lysine and methionine and decreased protein efficiency.

Diet 10 was underheated and produced weight gain which was significantly poorer than the control diet. The growth suppression was associated with the toxic trypsin inhibitor which was not completely destroyed during extrusion process (Sloan et al., 1971).

Feed utilization: At 8 weeks, there was no significant difference in feed utilization between diets 3, 4, 5, 6, 8 and the control diet (Table 4). Diets 9 and 10 were significantly better than the control with feed utilization of 1.657 and 2.017, respectively, as compared to 2.317 in the control diet. Except diets 6 and 4, which were slightly poorer than the control, all other diets were better utilized.

Mortality: The total mortality was 5% in each experiment. In experiment I, the greatest mortality of 1.66% occurred in peanut meal diet 2. The chicks were thin and poorly feathered. This could be associated with lysine and methionine deficiency.

In experiment II, the greatest mortality, of 2.64%, was due to feeding the diets containing charred peanuts and overheated soybeans. Probably birds died from nutrient deficiency.

SUMMARY AND CONCLUSIONS

Two experiments were run in which peanut meal, and roasted and ground soybeans and peanuts, and full-fat soybeans and peanuts singly and in combination were fed to broiler-strain chickens. Nine experimental diets and a corn-soybean meal control diet were used. A 24% protein starter and

a 20% protein finisher diet were fed for 0-4 and 4-8 weeks, respectively, in wire-floor cages.

Pooled analysis of variance of the data from the two experiments could not be computed because some physical interference such as overheating or underheating, and amino acid supplementation in experiment II. However, some conclusions may be drawn on the basis of the diets which were not supplemented with amino acids in both experiments and those diets which performed poorly in experiment I but responded favorably to amino acid supplementation (Table 5).

The following conclusions may be drawn:

1. Full-fat soybean, extruded or roasted and ground, as a sole source of protein in broiler diets was adequate in amino acids and produced weight gain and feed utilization which were equal or better than the corn-soybean meal diet.

2. When one-half of soybean protein, roasted and ground or extruded, was replaced by one-half of full-fat peanuts, extruded or roasted and ground, the diet was adequate in required amino acids and produced weight gain and feed utilization which were equal or better than the corn-soybean meal control diet.

3. Peanut meal as the main source of protein in broiler diet was deficient in lysine and methionine. Balancing the deficiency with calculated amounts of 0.25% L-lysine and 0.06% D-L methionine in the 24% protein diet produced weight gain which was not statistically different from the corn-soybean meal control diet.

4. Full-fat peanuts, extruded or roasted and ground, as the main source of protein was deficient in lysine, methionine and threonine. It

was sticky to grind or extrude, mix and feed. However, the supplementation of 0.25% L-lysine and 0.2% D-L methionine to the extruded diet produced weight gain which was not significantly different from the control diet, but feed utilization was significantly better than the control diet.

5. When one-half of full-fat soybean protein, extruded or roasted and ground, was replaced by one-half of peanut meal protein, the diet was slightly low in lysine and produced weight gain and feed utilization which were significantly poorer than the control diet. Supplementation of 0.04% L-lysine produced weight gain and feed utilization which were not statistically different from the control diet. It was slightly poorer than the control diet and this could be associated with some overheating in the roasted form and underheating in the extruded form.

The fat level of 23.20% of the diet with balanced amino acid had good texture, flowability and stimulated good growth. It was observed that 38.52% fat in broiler diets created texture problems. The feed was sticky and difficult to grind, mix and feed.

Further work is needed which would investigate the economics of feeding these diets, and to establish the level of peanut meal which could replace some full-fat soybean to obtain adequate lysine in the diet.

ACKNOWLEDGMENTS

The author is indebted to Dr. Charles L. Norton, Head, Department of Dairy and Poultry Science, Kansas State University for providing facilities for conducting the research and for his critical thesis review.

The author wishes to extend his special gratitude to Dr. Paul E. Sanford, major professor, for his unfailing assistance in the arduous task of preparing the experimental diets, and for his constructive criticism and valuable suggestions during the experiment and in the preparation of the thesis. Appreciation is also expressed to Dr. Arthur D. Dayton, Department of Statistics for consultation and statistical analysis of the data.

Gratitude is expressed to Dr. Albert W. Adams, Department of Dairy and Poultry Science, and Dr. Charles W. Deyoe, Department of Grain Science and Industry, for their willingness to serve as members of the advisory committee and for suggestions with the thesis.

LITERATURE CITED

Almquist, H. J., 1972. Proteins and amino acids in animal nutrition. 5th Edition. pp. 6-8. S. B. Penick and Co., Agribiotics-Nutrition, New York.

Altschul, A. M., G. W. Irving, Jr. and W. F. Gilbeau, 1948. The nutritive value of peanut cake, meal, protein and non-protein residue for chicks. Poultry Sci., 27:402-407.

Anantharaman, K. and K. J. Carpenter, 1965. The effects of heat treatment on the limiting amino acids of groundnut flour for the chick. Abstracts of Nutrition Society Proceedings, 24:xxxii.

Anantharaman, K. and K. J. Carpenter, 1969. The effects of heat processing on the nutritional value of groundnut products. I. Protein quality of groundnut cotyledons for rats. J. Sci. Food and Agric. and Abstracts, 20:703-707.

Anderson, J. O. and R. E. Warnick, 1965. Amino acid deficiencies in peanut meal and in corn-peanut meal ration. Poultry Sci., 44:1066-1071.

Bielorai, Rachel, 1969. Comparative digestibility of groundnut and soybean meal in vitro and in chicks. J. Sci. Food and Agric. and Abstract, 20:345-348.

Bielorai, Rachel, Z. Harduf and Eugenia Alumot, 1972. The free amino acid pattern of the intestinal contents of chicks fed raw and heated soybean meal. J. Nutrition, 102:1377-1380.

Blaylock, L. G. and L. R. Richardson, 1950. Peanut meal, mixtures of soybean and cottonseed mixtures of soybean and peanut meals as sources of protein for baby chicks. Poultry Sci., 29:656-660.

Bouthilet, R. J., W. L. Hunter, C. A. Luhman, J. Ambrose and S. Lepkovsky, 1950. The metabolism of raw versus heated soybeans in birds with colostomies. Poultry Sci., 29:837-840.

Carew, L. B., Jr., F. W. Hill and M. C. Nesheim, 1961. The comparative value of heated ground unextracted soybeans and heated dehulled soybean flakes as a source of soybean oil and energy for the chick. J. American Oil Chemists Society, 38:249-253.

Carew, L. B., Jr. and M. C. Nesheim, 1962. The effect of pelleting on the nutritional value of ground soybeans for the chick. Poultry Sci., 41: 161-168.

Carew, L. B., Jr., M. C. Nesheim and F. W. Hill, 1962. An in vitro method for determining the availability of soybean oil in unextracted soybean products for the chick. Poultry Sci., 41:188-193.

Carew, L. B., Jr., Ruth Renner and F. W. Hill, 1959. Growth stimulating effect of soybean oil and unextracted soybean flakes in chick rations. Poultry Sci., 38:1183-1184.

Clandinin, D. R., W. W. Cravens, C. A. Elvehjem and J. G. Halpin, 1947. Deficiencies in overheated soybean oil meal. Poultry Sci., 26:150-155.

Coates, E. Marie, D. Hewitt and P. Golob, 1970. A comparison of the effects of raw and heated soybean meal in diets for germ-free and convectional chicks. British J. Nutrition, 24:213-225.

Daghir, M. J., B. Ayysh and P. L. Pellect, 1969. Evaluation of groundnut meal protein for poultry. J. Sci. Food and Agric. and Abstracts, 20: 349-354.

Douglas, C. R. and R. H. Harms, 1959. Peanut oil meal as source of protein in broiler diets. Poultry Sci., 38:786-790.

Driggers, J. Clyde and Fred R. Tarver, Jr., 1958. High peanut oil meal with fish meal-fish solubles blend in broiler diet. Poultry Sci., 37: 1107-1111.

Featherston, W. R. and J. C. Rogler, 1966. A comparison of processing conditions of unextracted soybeans for utilization by the chick. Poultry Sci., 45:330-336.

Fisher, Hans, 1964. The amino acids in groundnut meal provided at optimal and suboptimal protein levels to growing chickens. J. Science of Food Agric. and Abstracts, 15:539-542.

Fisher, Hans, 1965. Further studies on the limiting amino acids in differently processed groundnut meals. J. Sci. Food Agric. and Abstracts, 16:390-393.

Food Agricultural Organization, 1966. Agricultural Development in Nigeria 1965-1980. William Clowes and Sons Ltd., London and Beccles.

Grau, C. R., 1946. Protein concentrates as amino acid sources for chicks: corn gluten meal, cotton seed meal and peanut meal. J. Nutrition, 32: 303-310.

Hains, P. C. and R. L. Lyman, 1961. Relationship of pancreatic enzyme secretion to growth inhibition in rats fed soybean trypsin inhibitor. J. Nutrition, 74:445.

Hammond, John C., 1944. Partial substitutes for soybean meal. Poultry Sci., 23:78.

Hayward, J. W. and F. H. Hafner, 1940. The supplementary effect of cystine and methionine upon the protein of raw and cooked soybeans as determined with chicks and rats. Poultry Sci., 20:139-150.

Hayward, J. W., J. G. Halpin, C. E. Holmes, G. Bohstedt and E. B. Hart, 1937. Soybean oil meal prepared at different temperatures as a feed for poultry. Poultry Sci., 16:3-14.

Heuser, G. F., L. C. Norris and J. McGinnis, 1946. Vegetable protein concentrates fed alone and in combination with soybean oil meal and fish meal as the chief supplementary protein in chick starting rations. Poultry Sci., 25:130-136.

Hull, S. J., P. W. Waldroup and E. L. Stevenson, 1968. Utilization of unextracted soybeans by broiler chicks: influence of pelleting and regrinding on diets with infrared cooked and extruded soybeans. Poultry Sci., 47:1115-1120.

Lepkovsky, S., F. Faruta and Mildred K. Dimick, 1971. Trypsin inhibitor and the nutritional value of soybeans. British J. Nutrition, 25: 235-240.

McOsker, E. Don, 1962. The limiting amino acid sequence in raw and roasted peanut protein. J. Nutrition, 76:453-458.

Mitchell, R. J., P. W. Waldroup, C. M. Hillard and K. R. Hazen, 1972. Effects of pelleting and particle size on utilization of roasted soybeans by broilers. Poultry Sci., 51:506-509.

Mustakas, G. C. and E. L. Griffin, Jr., 1964. Production and nutritional evaluation of extrusion-cooked full fat soybean flour. J. American Oil Chemist Society, 41:607-614.

Nelson, S. Talmadge, 1970. Feeding full fat soybeans to poultry. Proceeding, Twenty-fifth Kansas Formula Feed Conference.

Nesheim, M. C., 1961. Recent studies on factors affecting the nutritive value of soybean products. Proceeding, Cornell Nutrition Conference for Feed Manufacturers.

Neuccere, Navin J., Edith J. Conkerton and Albert N. Booth, 1972. Effect of heat on peanut proteins. II. Variations in nutrition quality of the meals. J. Food and Agric. Chemistry, 20:256-258.

Pieterse, P. J. S., 1963. Biological evaluation of the protein of groundnut oil cake meal. South African Agric. Sci., 6:541-548.

Renner, Ruth and F. W. Hill, 1960. Studies of the effect of heat treatment on the metabolizable energy value of soybean and extracted soybean flakes for the chick. J. Nutrition, 70:219-225.

Runnels, T. I., 1961. Processed whole soybeans as an ingredient in broiler diets. Proceedings, Distillers Feed Conference, Ohio.

Scott, M. L., M. C. Nesheim and R. J. Young, 1969. Nutrition of the chicken. M. L. Scott and Associates, Ithaca, New York. pp. 24, 397, 398.

Sloan, D. R., T. E. Bowen and P. W. Waldroup, 1971. Expansion extrusion processing of corn, milo and raw soybeans before and after incorporation in broiler diets. Poultry Sci., 50:257-260.

Snedecor, W. George and William G. Cochran, 1971. Statistical Methods. 6th Edition. The Iowa State University Press, Ames, Iowa, U.S.A.

Tian Fuh, Shen, H. R. Bird and M. L. Sunde, 1970. Cooked full fat soybeans for turkey poults. Poultry Sci., 49:1738-1740.

Waibel, Paul, 1972. Full fat soybeans. Feedstuffs, 44(8):28.

Waldroup, P. W. and R. H. Harms, 1963. Amino acid supplementation of peanut meal diets for broiler chicks. Poultry Sci., 42:652-656.

Warnick, R. E. and J. O. Anderson, 1968. Limiting essential amino acids in soybean meal for growing chickens and the effects of heat upon availability of the essential amino acids. Poultry Sci., 47:281-287.

Wessels, J. P. H., 1967. A comparison of different peanut meals to amino acid supplementation in chicks. S. African J. Agric. Sci., 10:113-121.

Westfall, R. J. and S. M. Hauge, 1948. The nutritive quality and trypsin inhibitor content of soybean flour heated at various temperatures. J. Nutrition 35:379-388.

White, C. L., D. E. Green, P. W. Waldroup and E. L. Stevenson, 1967. The use of unextracted soybeans for chicks. Poultry Sci., 46:1180-1185.

Wood, A. S., J. D. Summers, E. T. Moran, Jr. and W. F. Pepper, 1971. The utilization of unextracted raw and extracted full fat soybean by the chicks. Poultry Sci., 50:1392-1398.

APPENDIX

Table A-1. Composition of 24% protein control and experimental starter diets 0-4 weeks of age, experiments I and II.

Ingredients	Quantity Percent					
	D-1 (Control)	D-2	D-3 and 5[1]	D-4 and 6[2]	D-7 and 9[3]	D-8 and 10[4]
Yellow corn, ground	27	29.5	23	26.5	7.5	15.85
Sorghum grain, ground	27	29.4	23	26.5	7.5	15.85
Soybean meal, solv. ext. 44% prot.	36.31	--	--	--	--	--
Roasted ground soybean	--	--	44	21.05	--	23.7
Peanut meal, 50% prot.	--	31.1	--	16.0	--	--
Roasted peanut, ground, 26% prot.	--	--	--	--	75.0	34.6
Alfalfa meal, dehy. 17% prot.	2.0	2.0	2.0	2.0	2.0	2.0
Fish meal, 60% prot.	4.0	4.0	4.0	4.0	4.0	4.0
Distillers dried solubles	1.5	1.5	1.5	1.5	1.5	1.5
Calcium carbonate	1.0	1.0	1.0	1.0	1.0	1.0
Dicalcium phosphate	1.0	1.0	1.0	1.0	1.0	1.0
Sodium chloride	0.5	0.5	0.5	0.5	0.5	0.5
Total	100.0	100.0	100.0	100.0	100.0	100.0
Added per 100[5]						

[1]Contains 44% extruded soybean.

[2]Contains 21.05% extruded soybean.

[3]Contains 75% extruded peanut.

[4]Contains 23.7% extruded soybean, 34.6% extruded peanut.

Table A-1 (continued)

[5]Added per 100 lb.[1]

Trace minerals mix[2]	23 grams
Vitamin A (100,000 I.U. units/gm)	15 grams
Vitamin D_3 (15,000 I.C.U./gm)	8 grams
B-Complex vitamin mix[3]	46 grams
D-L methionine	35 grams
Vitamin B_{12} (20 mg/lb)	10 grams
Choline chloride, 25% mix	40 grams
Coccidiostat (Amprol Plus-20%)	23 grams

[1]Added to all diets.

[2]Trace mineral mix supplying by %: Mn 10; Fe 10; Cu I; Zn 5; I_2 0.3; Co 0.1.

[3]B-Complex vitamin mix supplying in mg/lb: riboflavin 8,000; pantothenic acid 14,720; niacin 24,000; choline chloride 80,000.

Table A-2. Composition of 20% protein control and experimental finisher diets 5-8 weeks of age, experiments I and II.

Ingredients	Quantity Percent					
	D-1 (Control)	D-2	D-3 and 5[1]	D-4 and 6[2]	D-7 and 9[3]	D-8 and 10[4]
Yellow corn, ground	32.5	34.5	30.0	32.5	17.0	25.0
Sorghum grain, ground	32.5	34.0	30.0	35.0	17.0	24.5
Soybean meal, solv. ext. 44% prot.	25.0	--	--	--	--	--
Roasted, ground soybean, 38% prot.	--	--	30.10	14.5	--	16.0
Peanut meal, 50% prot.	--	21.5	--	11.0	--	--
Roasted, ground peanut meal, 26% prot.	--	--	--	--	48.0	24.5
Alfalfa meal, dehy., 17% prot.	2.0	2.0	2.0	2.0	10.0	2.0
Fish meal, 60% prot.	4.0	4.0	4.0	4.0	4.0	4.0
Distillers dried solubles	1.5	1.5	1.5	1.5	1.5	1.5
Calcium carbonate	1.0	1.0	1.0	1.0	1.0	1.0
Dicalcium phosphate	1.0	1.0	1.0	1.0	1.0	1.0
Sodium chloride	0.5	0.5	0.5	0.5	0.5	0.5
Total	100.0	100.0	100.0	100.0	100.0	100.0
Vitamin and mineral supplements[5]						

[1]Contains 30.10% extruded soybean.

[2]Contains 14.5% extruded soybean.

[3]Contains 48% extruded soybean.

[4]Contains 16 extruded soybean, 24.5% extruded peanut.

[5]Same minerals and vitamins added per 100 as in Table 1.

Table A-3. Calculated amino acid content of the diets at 24% protein compared to NRC requirements.

	NRC	D-1	D-2	D-3 and 5	D-4 and 6	D-7 and 9	D-8 and 10
Arginine	1.4	1.76	2.14	1.74	1.90	2.67	2.15
Lysine	1.25	1.48	1.00[1]	1.44	1.21[1]	1.01[1]	1.24
Tryptophane	.23	.29	.27	.34	.30	.27	.31
Methionine	.86	.48	.39	.91	.64	.26[1]	.676
Cystine	.40	.43	.41[1]	.41	.41	.40	.41
Leucine	1.6	2.14	2.11	2.03	2.07	1.68	1.87
Isoleucine	.86	1.30	1.04	1.23	1.13	.99	1.12
Threonine	.80	.93	.798	.94	.86	.72[1]	.84
Phenylanine[2]	1.5	1.19	1.25	1.14	1.19	1.22	1.18
Valine	1.0	1.28	1.30	1.16	1.23	1.11	1.14
Histidine	.46	.55	.54	.53	.53	.53	.536
Glycine	1.15	1.24	1.40	1.32	1.36	2.49	1.86
Fat		2.53	2.93	10.01	6.32	38.52	23.20
Energy Me Cals/lb		1272.89	1342.44	1447.39	1394.24	1892.59	1652.77
C.P. ration		53:1	56:1	60.3:1	58:1	79:1	69:1

[1]Limiting amino acids: lysine and methionine.

[2]Tyrosine furnishes remaining deficiency in phenylanine.

Table A-4. Average 0-2 week weight gains and feed utilization for all lots, experiment I.

Diet No.	Lot No.	Gains in Grams	Kg Feed per Kg Gain
1	1, 2, 3	178.367	1.573
2	4, 5, 6	63.400	2.540
3	7, 8, 9	218.200	1.377
4	10, 11, 12	148.900	1.647
5	13, 14, 15	184.733	1.587
6	16, 17, 18	143.000	1.757
7	19, 20, 21	108.433	1.433
8	22, 23, 24	174.667	1.360
9	25, 26, 27	151.933	1.327
10	28, 29, 30	240.733	1.350

Ranked diets based upon Fisher's L.S.D. for weight gain.[1]

Ranked diets for weight gain   10   3   5   1   8   9   4   6   7   2

[1]Any lots not underscored by the same line are significantly different.

Table A-5. Average 2-4 week weight gain and feed utilization for all lots, experiment I.

Diet No.	Lot No.	Gains in Grams	Kg Feed per Kg Gain
1	1, 2, 3	416.366	1.957
2	4, 5, 6	124.967	3.223
3	7, 8, 9	434.833	1.720
4	10, 11, 12	350.433	1.990
5	13, 14, 15	403.066	1.757
6	16, 17, 18	331.866	2.110
7	19, 20, 21	269.533	1.417
8	22, 23, 24	397.200	1.577
9	25, 26, 27	367.466	1.553
10	28, 29, 30	497.000	1.653

Ranked diets for weight gain 10 3 1 5 8 9 4 6 7 2

Table A-6. Average 4-6 week weight gain and feed utilization for all lots, experiment I.

Diet No.	Lot No.	Gain in Grams	Kg Feed per Kg Gain
1	1, 2, 3	595.166	2.290
2	4, 5, 6	232.039	2.693
3	7, 8, 9	619.266	1.940
4	10, 11, 12	483.733	2.207
5	13, 14, 15	563.266	2.137
6	16, 17, 18	485.100	2.330
7	19, 20, 21	236.100	2.767
8	22, 23, 24	546.433	1.877
9	25, 26, 27	469.500	1.947
10	28, 29, 30	603.133	2.027

Ranked diets for weight gain   3   10   1   5   8   6   4   9   7   2

Table A-7. Average 6-8 week weight gain and feed utilization for all lots, experiment I.

Diet No.	Lot No.	Gain in Grams	Kg Feed per Kg Gain
1	1, 2, 3	624.867	2.593
2	4, 5, 6	322.010	2.483
3	7, 8, 9	576.566	2.577
4	10, 11, 12	567.600	2.677
5	13, 14, 15	615.233	2.427
6	16, 17, 18	532.533	2.650
7	19, 20, 21	349.233	2.313
8	22, 23, 24	609.400	2.170
9	25, 26, 27	511.100	2.350
10	28, 29, 30	643.100	2.297

Ranked diets for weight gain 10 1 5 8 3 4 6 9 7 2

Table A-8. Average four week (0-4 week) weight gain and feed utilization for all lots, experiment I.

Diet No.	Lot No.	Gain in Grams	Kg Feed per Kg Gain
1	1, 2, 3	594.733	1.840
2	4, 5, 6	188.367	2.990
3	7, 8, 9	653.003	1.603
4	10, 11, 12	499.333	1.887
5	13, 14, 15	587.800	1.703
6	16, 17, 18	474.866	2.003
7	19, 20, 21	377.967	1.380
8	22, 23, 24	571.866	1.507
9	25, 26, 27	519.400	1.490
10	28, 29, 30	737.900	1.553

Ranked diets based upon Fisher's L.S.D. for weight gain

Ranked diets for weight gain	10	3	1	5	8	9	4	6	7	2

Table A-9. Average six week (0-6 week) weight gain and feed utilization for all lots, experiment I.

Diet No.	Lot No.	Gain in Grams	Kg Feed per Kg Gain
1	1, 2, 3	1180.866	2.027
2	4, 5, 6	420.410	2.873
3	7, 8, 9	1272.300	1.767
4	10, 11, 12	983.066	2.043
5	13, 14, 15	1151.066	1.917
6	16, 17, 18	959.966	2.170
7	19, 20, 21	614.066	1.740
8	22, 23, 24	1118.300	1.690
9	25, 26, 27	988.900	1.707
10	28, 29, 30	1340.866	1.763

Ranked diets for weight gain 10 3 1 5 8 9 4 6 7 2

Table A-10. Average eight week (0-8 week) weight gains and feed utilization for all lots, experiment I.

Diet No.	Lot No.	Gains in Grams	Kg Feed per Kg Gain
1	1, 2, 3	1814.767	2.267
2	4, 5, 6	742.416	2.677
3	7, 8, 9	1848.866	2.020
4	10, 11, 12	1550.667	2.277
5	13, 14, 15	1766.300	2.093
6	16, 17, 18	1492.500	2.330
7	19, 20, 21	981.066	1.903
8	22, 23, 24	1727.700	1.860
9	25, 26, 27	1500.000	1.920
10	28, 29, 30	1983.967	1.930

Ranked diets for weight gain: 10 3 1 5 8 4 9 6 7 2

Table A-11. Average 0-2 week weight gains and feed utilization for all lots, experiment II.

Diet No.	Lot No.	Gains in Grams	Kg Feed per Kg Gain
1	1, 2, 3	197.167	1.573
2	4, 5, 6	131.900	1.767
3	7, 8, 9	190.467	1.500
4	10, 11, 12	180.033	1.650
5	13, 14, 15	140.933	1.887
6	16, 17, 18	145.667	1.733
7	19, 20, 21	25.467	4.750
8	22, 23, 24	95.833	1.990
9	25, 26, 27	120.667	1.793
10	28, 29, 30	123.567	1.730

Ranked diets for weight gain   1 3 4 6 5 2 10 9 8 7

Table A-12. Average 2-4 week weight gains and feed utilization for all lots, experiment II.

Diet No.	Lot No.	Gains in Grams	Kg Feed per Kg Gain
1	1, 2, 3	432.066	1.987
2	4, 5, 6	400.366	1.850
3	7, 8, 9	437.766	1.763
4	10, 11, 12	428.233	1.863
5	13, 14, 15	358.800	1.943
6	16, 17, 18	379.333	1.903
7	19, 20, 21	33.500	4.533
8	22, 23, 24	220.067	2.037
9	25, 26, 27	375.967	1.293
10	28, 29, 30	337.333	1.657

Ranked diets for weight gain 3 1 4 2 6 9 5 10 . 8 7

Table A-13. Average 4-6 week weight gains and feed utilization for all lots, experiment II.

Diet No.	Lot No.	Gains in Grams	Kg Feed per Kg Gain
1	1, 2, 3	526.667	2.463
2	4, 5, 6	521.400	2.303
3	7, 8, 9	502.467	2.533
4	10, 11, 12	483.167	2.597
5	13, 14, 15	448.633	2.620
6	16, 17, 18	459.767	2.650
7	19, 20, 21	138.500	1.613
8	22, 23, 24	332.333	2.483
9	25, 26, 27	515.833	1.577
10	28, 29, 30	495.567	1.957

Ranked diets for weight gain   1 2 9 3 10 4 6 5 8 7

Table A-14. Average 6-8 week weight gains and feed utilization for all lots, experiment II.

Diet No.	Lot No.	Gain in Grams	Kg Feed per Kg Gain
1	1, 2, 3	565.000	2.707
2	4, 5, 6	607.700	2.167
3	7, 8, 9	579.066	2.620
4	10, 11, 12	526.166	2.700
5	13, 14, 15	591.533	2.430
6	16, 17, 18	545.433	2.693
7	19, 20, 21	216.633	1.720
8	22, 23, 24	416.566	2.070
9	25, 26, 27	616.867	1.923
10	28, 29, 30	570.333	2.343

Ranked diets for weight gain   9   2   5   3   10   1   6   4   8   7

Table A-15. Average four week (0-4 week) weight gains and feed utilization for all lots, experiment II.

Diet No.	Lot No.	Gains in Grams	Kg Feed per Kg Gain
1	1, 2, 3	629.233	1.857
2	4, 5, 6	532.266	1.857
3	7, 8, 9	628.233	1.680
4	10, 11, 12	611.267	1.800
5	13, 14, 15	499.733	1.930
6	16, 17, 18	525.000	1.877
7	19, 20, 21	58.967	4.617
8	22, 23, 24	315.900	2.020
9	25, 26, 27	496.633	1.400
10	28, 29, 30	460.900	1.680

Ranked diets for weight gain   1 3 4 2 6 5 9 10 8 7

Table A-16. Average 0-6 week weight gains and feed utilization for all lots, experiment II.

Diet No.	Lot No.	Gains in Grams	Kg Feed per Kg Gain
1	1, 2, 3	1155.900	2.130
2	4, 5, 6	1053.666	2.060
3	7, 8, 9	1130.700	2.053
4	10, 11, 12	1094.433	2.150
5	13, 14, 15	948.367	2.253
6	16, 17, 18	984.767	2.237
7	19, 20, 21	197.467	2.437
8	22, 23, 24	648.233	2.253
9	25, 26, 27	1012.466	1.493
10	28, 29, 30	956.466	1.820

Ranked diets for weight gain   1   3   4   2   9   6   10   5   8   7

Table A-17. Average eight week (0-8 week) weight gains and feed utilization, experiment II.

Diet No.	Lot No.	Gain in Grams	Kg Feed per Kg Gain
1	1, 2, 3	1720.900	2.317
2	4, 5, 6	1661.366	2.100
3	7, 8, 9	1709.800	2.247
4	10, 11, 12	1620.600	2.330
5	13, 14, 15	1539.900	2.313
6	16, 17, 18	1530.200	2.400
7	19, 20, 21	414.100	2.083
8	22, 23, 24	1064.800	2.183
9	25, 26, 27	1629.333	1.657
10	28, 29, 30	1526.800	2.017

Ranked diets for weight gain	1	3	2	9	4	5	6	10	8	7

THE NUTRITIVE VALUE OF PEANUT MEAL, SOYBEAN MEAL AND VARIOUSLY PROCESSED FULL-FAT PEANUTS AND SOYBEANS AS SOURCES OF PROTEIN IN BROILER DIETS

by

ALFRED O. ADUKU

B. Sc., Ahmadu Bello University, Zaria, 1971

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Poultry Science

Department of Dairy and Poultry Science

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1973

Two experiments were conducted in which broiler chicks were fed infrared cooked, ground, full-fat peanuts and soybeans, their extruded forms, and peanut meal as the main sources of supplementary protein. Combination of these were also fed up to one-half of each vegetable protein to formulate a 24% protein starter and 20% protein finisher diets for 0-4 and 4-8 weeks, respectively. Corn-sorghum grain-soybean meal diet was used as the control diet.

Weight gain and feed utilization were obtained every 2 weeks from chick weight gain and feed consumed.

It was found that peanut meal as a single source of protein was deficient in lysine and methionine while full-fat peanuts were deficient in these and threonine. Weight gains and feed utilization were significantly poorer than the soybean meal control diet.

When peanut meal replaced one-half of soybean protein in the diet, lysine was deficient and poorer weight gain and feed utilization resulted.

When full-fat peanut protein replaced one-half of full-fat soybean protein, weight and feed utilization were equal or better than the control diet. Similar favorable results were obtained with full-fat soybeans.

Nonsignificant weight gains and feed utilization were obtained by supplementing with calculated levels of the deficient amino acid.