EFFECTS OF BOILING AND BOILING/ROASTING ON SUBSEQUENT UTILIZATION OF SOYBEANS BY CHICKENS

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ABSTRACT

EFFECTS OF BOILING AND BOILING/ROASTING ON SUBSEQUENT UTILIZATION OF SOYBEANS BY CHICKENS

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Occasional shortages and rising prices of vegetable protein sources for poultry ration formulations have created the necessity for a continuous search for alternative sources of vegetable protein to replace the conventional oil meals in poultry rations. The purpose of this study was to determine the extent to which meals made from boiled soybeans and boiled/roasted soybeans could be used in broiler and layer rations without adverse effects on the growing and laying performances.

Three feeding experiments were conducted. The first feeding experiment lasting 7 1/2 weeks involved 336 Hubbard Broiler chicks. Its objective was to evaluate the responses of the chicks to three levels (10, 20 and 30 percent) each of the boiled soybean meal (boilsoy) or of the boiled/roasted soybean meal (roastsoy) diets, respectively.

In the second broiler feeding experiment involving 448 chicks, the effects of supplementing each of the levels (10, 20 and 30 percent) of the boilsoy and the roastsoy with 0.2% and 0.4% DL-Methionine in broiler diets were evaluated. The conventional 48% protein, soybean meal diets served as

control diets for the two broiler studies. The criteria for evaluation for these two broiler studies included final body weight, body weight gain, feed consumption, feed conversion, pancreas weights and rate of mortality.

Sensory evaluation of the baked meat samples taken from birds fed: (a) the SBM-control diet, (b) 30% boilsoy diet and (c) 30% roastsoy diet was obtained using a consumer-type panel. A combination of hedonic and ranking evaluations were requested for color, odor, flavor, juiciness, tenderness and overall acceptability.

The third feeding experiment involved 224 laying hens. Three levels each (7.5, 15 and 22.5 percent) of boilsoy and roastsoy were fed for five, 28-day periods. The criteria for evaluation included total egg numbers per bird, hen-day egg production, hen-housed egg production, egg weights, pancreas weights, feed consumption, feed efficiency per dozen eggs, change in body weights and mortality rate.

Finally, a urease activity test was conducted on four types of soybean meals (48% protein, solvent extracted soybean meal, raw soybean meal, boiled soybean meal and boiled/roasted soybean meal) to determine the effectiveness of the amount of heat applied to the various soybeans. The following results were obtained:

a. From the three feeding experiments, it was concluded that up to 22.5% and 25% roastsoy may be incorporated into layer and broiler diets, respectively, without adverse effects on the laying or the growing performance of the birds provided the rations contain adequate sources of methionine.

b. Boilsoy should not exceed 10% of broiler diets or 15% of layer diets. Further studies would be required to determine if levels higher than the levels specified above might have adverse effects.

c. The boilsoy and roastsoy diets had no hypertrophic effect on the pancreases of the broilers or the layers fed.

d. There was no beneficial effect from supplementing either the boilsoy or the roastsoy broiler diets with DL-Methionine at the 0.4% level when compared with 0.2% supplement.

e. Boilsoy and roastsoy, each at 30 percent of the rations, had no adverse effects on the broiler meat quality when compared with the meat from the birds fed the control diet. The meat from the birds fed the roastsoy diet received the significantly highest overall ranking for eating quality ($p < 0.05$) and had the highest scores for most of the meat quality characteristics considered.

f. Urease activity tests showed that the condition of time-temperature-moisture combination applied to the boilsoy and roastsoy during the processing improved their nutritional qualities to levels of extracted soybean meal in this study.

Dedicated to my beloved wife Dupe

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TABLE OF CONTENTS

Page

Page

LIST OF TABLES

Table		Page

Table		Page

LIST OF FIGURES

LIST OF ABBREVIATIONS, SYMBOLS AND DEFINITIONS OF TERMS

TI	Trypsin Inhibitors
SBM	Refers to 48% protein, solvent extracted soybean meal which supplies most of the vegetable protein in the control diets for all the feeding experiments.
Boilsoy	Refers to the name boiled soybeans which had been ground into a meal. This was one of the two soybean meals evaluated in this study. This product was prepared by boiling soybeans in water at 90.5°C for 50 minutes. The boiled beans were dried and ground into a meal.
Roastsoy	Refers to the names boiled/roasted soybean, oil roast soybean or roasted soybean. This product is prepared by first boiling the soybeans as described above for boiled soybeans. The boiled beans were air dried overnight before roasting in oil. The split beans, the overroasts and the sediments of fat and condiments that settle at the bottom of the roasting compartment of the machine--all of which were considered not suitable for human consumption, were collected and

ground up into a meal. Currently, the roastsoy is of no value to the oil roast soybean industry and is being thrown away as wastes. However, in the near future, this by-product may attract some value as the industry expands and it becomes possible to utilize the roastsoy as a livestock feed ingredient.

Treatment — Refers to the types of soybean meal diets used in the experiments. These are SBM, boilsoy and roastsoy diets. It also refers to raw soybean, boilsoy, roastsoy and SBM in the urease tests.

Levels — Refers to 10, 20 and 30 percent levels of the soybean types in the rations for the broiler feeding Experiments I and II and to 7.5, 15 and 22.5 percent levels for the layer feeding Experiment III.

INTRODUCTION

Commercially processed soybean meal is the major source of vegetable protein for livestock and poultry feeds in the United States which now produces over 70 percent of the world's soybean output. Over 45 percent of the soybean meal output is consumed by the poultry industry. The protein quality or amino acid balance of soybean probably excels that of any other plant protein product available for use in animal feeds.

The U.S. soybean processing industry started in 1915 when soybeans were first processed in a North Carolina cottonseed oil mill. Early soybean processing was through a screwpress or expeller equipment. The first solvent extraction plant was put into operation in 1934. There was a gradual, but definite shift from mechanical extraction to continuous solvent extraction operations. Since the early 1950's, the availability of mechanically processed soybean meal has been limited. Today, approximately 15 million metric tons of soybean meal produced in the U.S. are processed in large, modern, solvent extraction operations.

There are about 20 soybean processing operations in the U.S. crushing over 2,000 tons of soybeans per day (Smith, 1977). The trend is for larger, more efficient operations. The advantage of large operations to the nutritionist is that the soybean meal produced is a more uniform product of superior quality and backed by an intensive quality assurance program. Since soybean oil is a major edible oil and it is of greater value per unit weight than the meal, removal of about 5 kilograms of oil per bushel of soybeans allows both the oil and the meal to contribute to the value of the raw material. The occasional low soybean oil prices plus the acceptance of the concept of high energy diets for broilers has created an interest in feeding full-fat, unextracted soybeans with their characteristic high oil content.

Most farmers would prefer to feed unheated soybeans to chickens in order to eliminate the cost of transporting the raw materials to the processor and back to the farm as well as the heating costs. This has not been the case because it has been known for over six decades that proteins in raw soybeans have a low nutritive value and that cooking brings this value close to that of meat and milk products. The heat and moisture conditions of processing inactivate most of the antinutritional properties that cause poor growth and other poor results obtained when raw soybean diets are fed to monogastrics. Processing also improves the utilization of protein and energy contained in the soybean.

Currently, the world is experiencing an increasing scarcity and rising prices of vegetable protein feed ingredients for use in animal feeds. This condition has necessitated a continuous search for alternative vegetable protein sources for poultry and livestock ration formulations. A new industry processing oil roast soybeans for human consumption started in the early 1970's. Two important waste products of this industry consist of--(a) boiled soybeans consisting mainly of the split beans and (b) overroasts mixed with condiments and fats (referred to as roastsoy or roasted soybeans hereafter) that settle at the floor of the roasting tunnel of the machine. One of such soybean roasting plant is located in Mason, near Lansing, Michigan. This plant, owned by Inari, processes about one and a half tons of soybean per day. A little over one percent of the processed beans end up as waste by-products and over 90 percent of this is overroasts. The oil roast soybean industry is still very young. Currently, about six tons of soybeans are processed daily by the four main plants known to exist in the U.S.A. The market for soybeans for human consumption has continued to grow both in the U.S.A. and in Europe. If the industry continues to grow at the current rate, a substantial amount of the waste by-products (boiled and overroast) would result in the near future.

Furthermore, there are some areas of the world where a soybean oil extraction industry does not exist. It would be beneficial for those areas if a domestic use could be established for the locally produced soybeans.

The objective of this study was to evaluate the feeding values of both the boiled and overroast soybeans in poultry rations. It was also hoped that the study would contribute to the existing knowledge on the various methods for processing raw soybeans for poultry ration formulations.

LITERATURE REVIEW

During the past four decades, soybeans have become the major source of vegetable proteins for poultry and livestock feeds in the United States and in many other areas of the world. Legumes in general are known to contain a number of factors which in one way or another may exhibit deleterious effects when fed to monogastric animals. Hayward and Hafner (1941) and Bornstein and Lipstein (1963) showed that growth inhibition in chicks fed raw soybeans is not always due to decreased feed intake. Among the growth inhibitory factors found particularly in soybeans are Trypsin Inhibitors (TI), goitrogenic substances, saponins and a hemagglutinin. Soybeans have two special enzymes, urease and lipoxidase. Urease converts urea to ammonium and carbon dioxide. Dang and Visek (1964) suggested that the phenomenon of in vivo urea hydrolysis by urease may have considerable physiological significance. Urease is the only enzyme known to hydrolyze urea in vivo. Its activity in mammals is largely confined to the gastro-intestinal tract (Kornberg and Davies 1955). Death in animals has been produced by urea injection and its resulting ammonemia (Barnett and Addis 1917). Lipoxidase catalyzes oxidation of unsaturated fatty acids with the production of peroxides which interact with other compounds to cause harmful effects in vivo.

Work on Trypsin Inhibitors

Of major concern in monogastric species is the trypsin inhibitor (TI) compound which inhibits digestibility of proteins.

The rapid change in status of soybean meal to the principal source of protein about 60 years ago has served to stimulate a vast amount of research regarding the possible nutritional significance of TI (Liener 1977). Osborne and Mendel (1917) made a significant observation that heat treatment of soybeans would improve their nutritional value. These workers reported that rats fed raw soybeans as the sole source of proteins failed to grow normally while those on cooked soybean diets grew at a normal rate. Kunitz (1945) subsequently isolated from soybeans a protein which had the unique property of combining with trypsin to form an inactive complex. Rackis and Anderson (1964) were able to isolate four different types of TIs from soybeans by DEAE--Cellulose chromatography. Wang *et al*. (1972) showed that TIs may exist in two forms. There is the heat resistant, inactive, and bound form and the unbound active form.

Wang *et al*. (1972) studied the activity of soybean TIs of boiled soybeans fermented by *Rhizopus oligosporus saito*. They found that the extracts prepared from fermented boiled soybeans showed higher TI activity than extracts prepared from unfermented, boiled soybeans. The extractable soybean TI increased as fermentation progressed and reached a maximum after 48 hours of incubation. The increased TI was not synthesized by the mold. They proved that active TI was liberated from the heat resistant, inactive, bound form by R. Oligosporus. Once released, the inhibitor was readily inactivated by heat.

Liener (1977) reported on the previous studies conducted by himself and his associates to determine to what extent the poor nutritive value of soybeans was actually caused by the TI itself. Working with 26 soybean varieties representing low, medium, and high levels of TI activity, they observed no correlation between TI activities and Protein Efficiency Ratios but they observed a significant level of correlation (negative) between pancreas weights and Protein Efficiency Ratios (PER) in rats. From this they speculated that there must be present in raw soybeans some other factors which were totally unrelated to the TI which was also capable of causing pancreas enlargement and inhibition of growth.

In further studies with rat diets, Liener (1977) reported that he and his associates compared unheated soybean proteins from which the inhibitor had been selectively removed by affinity chromatography using immobilized trypsin (sepharose--bound trypsin) with the original soy protein still containing the inhibitor as well as an extract which had been subjected to the usual heat treatment normally applied when making soy flour. Their results showed that, although the removal of the inhibitor increased the PER from 1.4 to 1.9, heat treatment effected a greater increase to PER of 2.7 similar to what one gets with soy flour itself. From their data they figured that about 40% of the difference in PER between raw and heated soybean protein may be attributed to the TI. They also observed that the removal of the inhibitor helped to decrease the size of pancreas by 40% of the decrease obtained by heat treatment.

From these studies Liener and co-workers realized that the TI may not be the only factor responsible for the poor growth response one obtains with raw legume diets. They therefore considered the possibility that the fact that the protein itself had not been heated might be responsible for the poor growth and pancreas hypertrophy not accounted for by the inhibitor. The in vitro digestion with trypsin was tested with the protein extract from which the inhibitor had been removed. The result was compared with similar tests on the original extract before and after heat treatment. This test also confirmed the in vivo results as they observed again, about 40% of the difference in digestibility between the raw and heated soybean extract can be attributed to the trypsin inhibitor.

Mode of Action of Trypsin Inhibitors (TI)

Ham and Sandstedt (1944) discovered a substance in raw soybeans which greatly retarded the activity of typsin in vitro. This discovery was confirmed by other workers and this led to the suggestion that growth depression caused by raw soybeans was the result of incomplete intestinal proteolysis.

Borchers et al. (1947) stated that the trypsin inhibitor from soybean acted not by combining with the substrate, but by acting on trypsin either to prevent its combination with the substrate or to prevent the dissociation of the enzyme--substrate complex. Lyman and Lepkovsky (1957) studied the effect of soybean TIs on the size of pancreas of rats and its secretion of enzymes. They found that feeding either crude TI or raw soybean meal enlarged the pancreas and greatly stimulated its activity. Shortly after intake started, the trypsin in the gut was reduced but this low tryptic activity was followed by an increased secretion of the enzymes so that after six hours, the secretion of trypsin was three times greater than normal. This led them to conclude that the growth inhibition caused by soybean TI was due to an endogenous loss of protein produced by a hyperactive pancreas rather than insufficient intestinal proteolysis. Other workers, Lyman and Lepkovsky (1957) and Booth et al. (1960) reported further work which suggested that there may be sufficient loss of essential amino acids in the feces due to the enzymes secreted by the pancreas, to reduce the nutritive value of the soybean protein.

Being of pancreatic origin, the endogenous protein, according to Lyman and Lepkovsky (1957), consisted largely of such enzymes as trypsin, chymotrypsin and amylase which are very rich in cystine. Since much of the cystine required for biosynthesis of these proteins is presumably derived from methionine, an accelerated rate of synthesis of these enzymes in the pancreas would in effect deplete the rest of the body tissues of methionine. Knowing that corn-soy diets are normally deficient in sulfur-containing amino acids it is not surprising, therefore, that methionine supplementation appears to effectively alleviate most of the growth depression caused by the inhibitor despite the persistence of pancreatic hypertrophy (Khayambashi and Lyman 1966; Booth et al., 1960).

Green and Lyman (1972) and Niess et al. (1972) reported that it is the level of active trypsin in the intestines which controls the amount of enzymes secreted by the pancreas through a feedback inhibition. Low levels of active trypsin in the gastro-intestinal tract, as would be the case in the presence of a trypsin inhibitor, would cause the pancreas to respond by producing more enzyme. It is not known whether this effect is mediated through the action of pancreozymin.

Liener (1977) maintained that although the growth inhibition of the trypsin inhibitor cannot be explained solely by the inhibition of intestinal proteolysis, there is no doubt that intestinal proteolysis plays a significant role in the overall nutritive properties of soybean protein. This will be true particularly if the trypsin produced by the pancreas is not sufficient to neutralize all the inhibitor present in the intestinal tract. In this case, the proteolysis of intact protein would be depressed resulting in increased fecal nitrogen as is generally observed in animals receiving diets containing the inhibitor.

Effect of Heat Treatment on the Nutritional Values of Soybeans

Numerous workers have demonstrated the existence of a definite relationship between the amount of heat applied and the nutritive value of soybeans (Hayward et al., 1936). Heat treatment destroys most of the inhibitory properties and renders the sulfur amino acids more available (Hayward and Hafner, 1941). Heat also increases the energy value of the raw beans (Scott et al., 1971). According to Melnick et al. (1946), optimum utilization of proteins requires that the essential amino acids must not only be available for absorption, but they must be liberated during in vivo digestion at rates permitting their mutual supplementation. From in vitro digestibility tests, they concluded that methionine was released earlier from heat processed soybean meal than from raw soybean meal. In the raw soybean meal, the release and absorption of amino acids occurred too late in the intestinal tract to permit optimum supplementation by other amino acids. The main problem in the search for effective processing methods for soybeans for feed use is to determine the amount of heat and moisture combination to sufficiently destroy the heat-labile growth inhibitors and yet not adversely affect the availability of the essential amino acids. Among the various heating methods that have been investigated to date included steam heating at various pressures, extruding, roasting with dry heat, infrared heating and microwave heating.

Clandinin et al. (1947) demonstrated a time--temperature relationship in producing soybean meals of high nutritional quality. They observed a rapid increase in the nutritive value of soybean meal for chicks when the length of heating was increased from 4 to 15 minutes at 121°C. However, as the heating time increased beyond 15 minutes there was a very drastic decline in the nutritional value of the meal. These workers found that the over-heated meal was deficient in vitamins as well as in the amino acids methionine and lysine.

Hayward (1951) in a review stated that moist heating, such as boiling or autoclaving soybeans or meal or the use of moist heat in the processing of soybean oil meal has been the most effective way to obtain the optimum biological value of soybean proteins. Dry heat or roasting may improve the protein of whole, uncracked raw soybeans, but if the seed coat or hull of the seed is broken as in ground soybeans or soybean meals, then dry heating is very ineffective. He also warned that although autoclaving can be effective, if the soybean is autoclaved for too long at high temperatures, the nutritional value of the protein would be impaired. This author pointed out that the impairment of biological value of soybean proteins from overheating is usually the result of destruction of one or more essential amino acids. When dry heating is employed, lysine is usually one of the first amino acids to be destroyed or rendered unavailable.

Riesen *et al*. (1947) investigated the liberation of essential amino acids from raw, properly heated and overheated soybean oil meals. They found that except for lysine, arginine and tryptophane, the amount of each of the essential amino acids liberated by acid hydrolysis from soybean oil meal was unaffected by heat treatment. The liberation of lysine, arginine and tryptophane was decreased by prolonged heating. The amount of each of the essential amino acids liberated by pancreatic hydrolysis was increased by excessive heat treatment. These investigators concluded that the trypsin inhibitor is not the only factor involved in the observed difference between the nutritive values of raw and properly heated soybean oil meal.

Renner *et al*. (1953) showed that large amounts of moisture can partially prevent the damaging effect of overheating soybean meal. Through both chick feeding trials and microbiological assays for lysine, they demonstrated that the detrimental effects of over-heating soybean meal could be partially prevented by addition of water prior to heat treatments.

Mattingly and Bird (1945) also experienced a similar result when they found that heating of soybeans at 105°C interfered with the beneficial effects of subsequent autoclaving to improve the nutritive value of the protein.

Fritz et al. (1947) in an experiment with turkey poults obtained best results when ground raw soybeans were autoclaved at 15 pounds pressure for 20 to 30 minutes. Dry heat was not as desirable as moist heat and the dry heat caused damage to the protein which was not readily corrected by mild hydrolysis or by additions of lysine and methionine. They also found that similar damage could be caused by excessive moist heat, but autoclaving at 15 pounds pressure must be continued beyond 1.5 hours to cause serious damage to the biological value of the proteins. Longenecker and Lo (1974) attempted to make a quantitative estimate of the bio-availability of methionine in a severely heated soybean product. The soybean was heated for 8 hours with live steam in an autoclave. The experiments were carried out with rats and one human subject. The technique involved adding DL-Methionine to the diets in order to bring the biological criteria back to the level of unheated soy concentrate. In rats, the criterion was the PER. In the human subject, the criterion was the difference between the average post-prandial plasma methionine and fasting plasma methionine. From these experiments, Longenecker and Lo estimated the methionine availability in the heated soy concentrate to be 54 percent of that in the unheated product. McGinnis and Evans (1947) found that heat damage to soybean protein could not be corrected by the addition of methionine, cystine, or lysine. They postulated that autoclaving soybeans improves the nutritive value by enhancing the availability of nutrients other than cystine or methionine.

Utilizing a steam-jacketed cooker, Rogler and Carrick (1961) heated whole soybeans with additional injected steam and ground soybeans without supplementary steam injection. They obtained better chick growth results for both experimental diets than for chicks fed a soybean meal ration with added soybean oil.

Rackis _et al_. (1975), using rats as experimental animals, examined the relationship of trypsin inhibitor activity to the nutritive value as affected by heat treatment which consisted of live steam at atmospheric pressure for various periods of time. The results indicated that pancreatic hypertrophy did not occur in the rats when as much as 46 percent of the trypsin inhibitor remained. They also indicated that 79 percent of the inhibitor had to be destroyed before maximum protein efficiency ratios could be observed. Destruction of this much of the inhibitor required nine minutes of heat treatment as described above.

Renner and Hill (1960) reported that autoclaved, ground soybeans were equally as effective in promoting rapid growth as the combination of autoclaved, extracted soybean flakes and soybean oil despite the lower absorbability of the oil supplied by the unextracted soybeans.

Carew et al. (1961) reported their experiment with autoclaved, dehulled, unextracted soybean flakes produced a growth rate and feed efficiency equal to that obtained with the combination of soybean meal and degummed soybean oil, while autoclaved, ground, unextracted soybeans were less satisfactory.

Gustafson et al. (1971) studied the nutritive value of soybeans treated in a microwave oven (frequency of 2,450 megahertz with an output of 0.8 kilowatts) for a total period of 20 minutes. The beans were ground, dried and extracted after heat treatment. They reported that feed conversion and pancreas weight for chicks fed the microwave heated soybeans was comparable to that of the control soybean meal diets and better than chicks fed a raw soybean diet.

Six decades after the original work of Osborne and Mendel, it is still not possible to identify all the components which are modified by moist heat to give such a marked improvement in the nutritive value of the soybean. Most of the reports indicate that two of the main effects are with protein quality and the energy content. There is a possibility that ammonia resulting from urea hydrolysis by the urease component of raw soybeans in vivo may be one of the toxins contributing to the detrimental effects of feeding raw soybeans to chickens.

Dang and Visek (1960) and Visek (1962) postulated that the improvement in gain and efficiency of rats and chicks immunized with jackbean urease is due to a decrease in ureolytic activity of the gastro-intestinal tract. This reduction in urea hydrolysis caused by an antiurease--urease reaction results in a decreased amount of ammonia which the body must detoxify. Therefore, energy is conserved for growth. Elevated blood ammonia and depressed blood urea levels were observed in rats, mice, rabbits and guienea pigs where injections of crystalline jackbean urease have been reported to be toxic (Dang and Visek, 1963).

Effect of Hemagglutinins on the Utilization of Raw Soybean by Chickens

Raw soybeans also contain hemagglutinins. Jaffe and Camejo (1961) have shown that the addition of purified phytohemagglutinin from the black bean markedly reduced the digestibility of the protein (casein) component of the diet. In vitro experiments with isolated intestinal loops, taken from rats fed the black bean hemagglutinin revealed a 50% decrease in the rate of absorption of glucose across the intestinal wall. Liener (1977) reported Jaffe (1960) that the action of the hemagglutinin was to combine with cells lining the intestinal wall, thus causing a nonspecific interference with the absorption of nutrients. Unfortunately heat treatment may not destroy all the hemagglutinin component of soybeans, hence cooked products may sometimes produce diarrhea and severe vomiting (Korte, 1973a, b). Low concentrations of hemagglutinins may also affect the utilization of some amino acids as demonstrated by a reduced excretion of sulfur in human urine after the ingestion of insufficiently heated beans (Korte, 1973b).

Effect of Age on the Utilization of Raw Soybeans by Chickens

Saxena *et al*. (1963b) reported that the susceptibility of chicks to the detrimental effects of raw soybean meal decreased with age. Alumot and Nitsan (1961) reported proteolytic activity in the intestines of the chicks fed raw soybean meal was almost completely inhibited up to three weeks of age but after the fourth week, proteolytic activity increased, approaching that of the control chicks at six weeks of age. Nesheim *et al*. (1962) reported dietary raw soybean meal depressed fat absorption in chicks at two weeks of age but not at four weeks. They further stressed that the marked effect of raw soybean meal on fat absorption was probably a true age difference and not merely an adaptation to a raw soybean meal diet.

Contrary to this, Bonstein and Lipstein (1963) reported intestinal proteolysis was completely suppressed during the first eight experimental days in eight week old birds fed raw soybean meal and that the birds recovered intestinal proteolysis completely after 21 to 28 days. This result, according to Bonstein and Lipstein, suggests that age does not seem to affect the sensitivity of chicks to improperly processed soybeans but tends to shorten their physiological adaptation process. They noticed this adaptive phenomenon could not adequately compensate for the initial inhibitory properties of the underprocessed soybean meal within a four week experimental period. Fisher et al. (1957) concluded that insensitivity of chicks to the growth inhibitors did not assert itself until after 14 weeks of age.

Yates (1963) also reported that sensitivity of poultry to injury by raw soybeans decreased with age up to the onset of egg production. His result indicated the need for an adjustment period to allow the pullets to effectively use raw soybeans for egg production. Yates therefore, suggested that if raw soybeans are to be used, they should be started before egg production to prevent excessive stress.

Carver et al. (1946), working with laying hens, reported raw soybean meal supported excellent egg production in all-mash diets that contained 13 percent protein. Griminger and Fisher (1960) also concluded that egg production and egg weight could be maintained on a practical diet in which the major source of protein was raw, unextracted soybeans. Among other workers that have reported satisfactory egg production with raw soybean diets for layers are Fisher and Griminger (1961), Saxena et al. (1963a, b), Summers et al. (1966), and Salman and McGinnis (1968).

In contrast, Hill and Renner (1963) observed a reduction in egg production and metabolizable energy values for raw soybeans when compared with heated soybeans for layers. Rogler and Carrick (1964) and Ogundipe and Adams (1974) also observed a definite reduction in egg production when ground raw soybean diets were fed to layers. Lack of agreement in some results on feeding raw soybeans might be due to the fact that some researchers worked with extracted soybeans while others worked with unextracted soybeans. It appears that many workers who obtained favorable results with raw soybean diets used supplemental methionine.

Effect of Supplementing Raw Soybean Diets with Methionine

The beneficial effect of supplemental methionine in raw soybean diets was demonstrated by Hayward and Hafner (1941). They compared raw and cooked soybean meals in chick diets when supplemented with either cystine or methionine or a combination of the two amino acids at 0.3 percent levels and without any amino acid supplementation. They concluded that the raw soybean diet was deficient in available cystine and methionine and that 0.3 percent supplemental methionine was effective and capable of replacing cystine in the diet while 0.3 percent cystine supplement could not replace methionine.

Yates (1963) concluded from two of his studies with raw soybeans involving supplemental methionine that raw soybeans could be used with satisfactory results in poultry diets when properly supplemented with methionine but he observed that methionine supplementation did not prevent pancreatic hypertrophy.

Fisher et al. (1957), working with raw soybean meal protein exclusively in a semi purified diet, noticed the importance of supplemental methionine which led them to conclude that raw extracted soybeans would support good egg production when properly supplemented with methionine and vitamin B_{12}. On the contrary, Yates (1963) did not observe any beneficial effect by supplementing raw soybean diets with vitamin B_{12}. Other researchers who have reported improvement of raw soybean layer diets by addition of supplemental methionine include Saxena et al. (1963a) and Salman and McGinnis (1968). Waldroup et al. (1969) have similarly demonstrated that effective utilization of raw soybeans in laying diets requires total sulfur amino acid (methionine and cystine) levels considerably higher than 0.53 percent as suggested by the National Research Council (1977).

Ogundipe and Adams (1974) also reported on the beneficial effects of supplementing raw soybean diets with DL-methionine. These workers obtained no significant difference in percent change in body weight of egg-type pullets at 20 weeks of age when they compared the pullets fed raw soybean diets starting from 10 weeks of age with those fed from 14 weeks of age. The raw soybean growing diet contained 0.5 percent supplemental DL-methionine. Ogundipe and Adams also observed that the percent hen-day production of the birds reared on raw soybean meal diet plus o.5 percent supplemental DL-methionine was significantly higher than that of birds fed the raw soybean meal growing diet without supplemental methionine (61.5 versus 56.8 percent). Also, the production of birds reared on raw soybean meal diet plus 0.5 percent supplemental DL-methionine followed by the soybean meal layer diet was nearly equal to that of the birds fed soybean meal diets during both growing and laying periods (68.8 versus 70.3 percent). They concluded from these observations that supplemental DL-methionine at 0.5 percent level improved the egg laying performance of birds fed the raw soybean meal growing diet.

Attempts to improve the utilization of raw soybean diets with essential amino acid supplements other than methionine and cystine have also been reported. Alminquist <u>et al</u>. (1942) obtained little or no benefit by supplementing raw soybean chick diets with choline or L-cystine. Hill <u>et al</u>.

(1953) with a mixture of all essential amino acids could not overcome the growth depression of chicks receiving raw soybean diets.

Booth *et al*. (1960) observed slow growth, reduced feed efficiency and pancreatic hypertrophy in rats fed a 14 percent protein raw soybean diet. Additions of four amino acids, 0.6% L-tyrosine, 0.6% DL-methionine and 0.2% DL-valine reversed the growth depression but not the enlarged pancreas. In the abnormal pancreas, they found that acini had lost their regular circular outlines and become jumbled without distinct lumens. The basilar portion of the hyperplastic acinar epithelium was intensely basophylic and increased at the expense of the zymogenic portion.

The Effects of Goitrogenic Factor in Soybeans on Chickens

Patton *et al*. (1939) was able to produce goiter experimentally in chickens fed a ration containing 25% soybean oil meal. According to Wilgus *et al*. (1941), soybean meal contains a goitrogenic factor which is insoluble in chloroform, hexane, diethyl ether, acetone and ethanol and is somewhat heat-labile. They claimed that this factor is capable of producing goiter in rats and that it can be removed or destroyed by fat solvents. Sharpless *et al*. (1939) reported that the goitrogenic factor of soybeans was partially inactivated by heat and that iodine would counteract the effect on the thyroid gland. Wilgus *et al*. (1941) also reported that soybean oil meal was goitrogenic to chickens but no detrimental effect other than that on the thyroid was observed. Wilgus and co-workers however, could not extract the goitrogenic factor in soybeans by fat solvents as reported by Sharpless and co-workers.

Yates (1963), in his attempt to stimualte growth by adding a hormone-like compound having thyroxine-like effect to the raw soybean diets could not improve the growth performance of the chicks.

Hayward (1951), in his review on the feeding of oil meal for livestock and poultry, commented that the goitrogenic tendency of soybean oil meal is of no particular economic importance since practical poultry rations containing soybean oil meal and known required levels of iodine produce marketable and apparently normal poultry.

Effect of Raw Soybean Diets on Egg Quality

Saxena *et al*. (1963a) observed no significant differences in the albumen and yolk quality measurements but they observed a greater incidence of blood spots in eggs laid by hens receiving raw soybean meal diets. On the contrary, Summers *et al*. (1966) observed no increased incidence of blood spots by feeding raw, unextracted soybean diets to laying hens. Summers and co-workers also reported no differences in Haugh units and shell weights but noticed a slight indication that, as the level of protein increased, egg weight increased in the groups fed raw, unextracted soybean meal diets. Bonstein and Lipstein (1972) found methionine as the first limiting amino acid in increasing egg size of corn-soybean diets. Linoleic acid was the next limiting amino acid.

Influence of Soaking on the Nutritive Value of Soybeans

There are various methods for processing soybeans for livestock feed or for human consumption. The choice of the process is important because it will involve differences in cost, acceptability and nutritive value. In processing soybeans for human consumption, soybeans are often pre-soaked in either hot or cold water before further processing is done.

Hand (1966) reported that soaking removes 1.5 to 15 percent of soybean solids. The composition of soak water after 24 hours of soaking at 2 °C indicates high values for non-protein nitrogen (NPN) and carbohydrate content. The carbohydrate content of soak water was about three times that of original dehulled beans and the NPN was about ten times as high as the original beans. Analysis of the soak water also revealed that there was a 60 percent decrease in oligosaccharides (stachyose) but only 5 percent diffused into the soak water. From this, they postulated that there could be two possible ways by which soaking can bring about changes in composition of soybeans. Firstly, by leaching of solutes and secondly, by *in situ* biochemical changes. The leaching effect appears to be more serious by soaking dehulled beans at elevated temperatures.

In another experiment in which soybean cotyledons were soaked for three hours at temperatures ranging from 25 to 65°C, analysis of the milk made from such soaked beans showed a fall in carbohydrate content from 15 to 7 percent while the lipid content rose from 54 to 58 percent. There was a slight drop in the yield of soy milk solids. They also found the biochemical changes in soaked beans to be similar to transformations occurring during germination since there was an increase in free amino acids at the expense of protein and some of the storage fats were converted to carbohydrates. They noticed the removal of undesirable substances by soaking. The soak water had a disagreeable flavor and would not support growth of weaning rats although its amino acid content was adequate.

Influence of Nutrition on Meat Quality

Sturkie (1976) reported body fat is the most variable item among the major body constituents. It varies not only with species, sex and age but also with the level of nutrition. Tissue lipids are derived from dietary lipids as well as from lipogenesis, therefore, fat intake influences not only the quantity of lipogenesis but also the quality of lipids in various tissues. Each species and each different tissue within a given species has a certain constant fatty acid composition. The consumption of significant amounts of lipids, however changes the fatty acid composition of tissue lipids to varying degrees.

Yule and McBride (1976) suggested that feeding greater than 5% rapeseed meal could produce off-flavors in chicken meat. Steedman et al. (1979) conducted a study involving the subjective evaluation by an untrained taste panel. The study was on the influence of rapeseed meal on the eating quality of chicken. These workers reported that inclusion of 15% span rapeseed meal (high glucosinolate variety) in broiler diets resulted in significantly lower flavor and overall acceptability scores for dark meat samples and flavor scores for broth samples than scores for dark meat and broth from chickens fed the control ration. There were no significant differences in juiciness attributable to ration. In another study by the same workers, they further reported that chickens fed rapeseed meal rations received slightly lower palatability scores than those fed the soybean meal control ration, but the differences were not significant. In contrast to the result of their first study, the second study showed that inclusion of 15% span rapeseed meal in broiler ration resulted in chicken which was judged acceptable in eating quality. Although there are lots of reports on the nutritive value of heat treated soybean meal, there is little or no information regarding the eating quality of broilers fed either boiled and boiled/oil roasted soybean meal rations.

Capacity of Female Chickens to Produce More Tender Meat

Sturkie (1976) reported that endogenous estrogen is responsible for the increase in plasma lipids that occur at the time of sexual development. Testosterone proprionate has no effect on the lipid level of male or female Japanese quail (Nirmalan and George, 1972).

Senior (1974) also reported a gradual rise in the plasma levels of estrogen in female birds as they approach sexual maturity. Chan and Common (1974) demonstrated that 17α--estradiol is a major phenolic steroid of hen's blood. Korenbrot *et al*. (1974) also demonstrated by radio immunoassay that 17β--Estradiol levels of plasma of ring doves vary according to their sexual stage and behavior as follows:

Females, isolated	40pg/ml or less
Females, males introduced	85pg/ml
Females, nest building	67pg/ml
Females incubating eggs	Not detectable

Estradiol was not detectable in the plasma of males at any of these stages.

Estrogen administration increases the blood lipid and the deposition of fat in tissues possibly making the bird fatter and more desirable as a meat bird. Not only tenderness, but also grade can be improved by estrogens in chickens and turkeys by virtue of increased subcutaneous fat deposits.

Factors Influencing Eating Quality of Broiler Meat

Quality grades of meat are primarily intended to reflect differences in eating quality. Quality, as used in grading meat, refers to its expected palatability, its tenderness, juiciness and flavor. Quality control of flavor in poultry is mainly preventing development of off flavors. If the feed contains too much oil from fish meal, or too much of the highly unsaturated fatty acids from any other source, the poultry meat may develop "fishy" or off-flavors. Other factors that may influence meat tenderness include processing procedures such as time for aging before cut cup, scalding temperatures and time (Cole and Magnar Ronning, 1974).

Urease Activity as an Indicator of Effective Cooking of Soybeans

Urease activity in legume seeds can be used as an indicator of enzyme destruction. Since urease is relatively easy and quickly analyzed, the soybean processing industry uses urease as an indicator of trypsin inhibitor (TI) destruction and of properly processed meal. According to Bird *et al*. (1947), the principle underlining the use of the urease test to determine the effectiveness of soybean heating procedure was described by Caskey and Knapp (1944). They realized that the intensity of the heat treatment required for development of high nutritive value in soybeans appeared to be the same as that required for the destruction of the enzyme urease and that inadequately heated soybean oil meals could be detected by measuring their urease content. Hayward (1967) demonstrated the relationship between protein efficiency, protein denaturization and urease activity. His results showed that the quality of protein increased with protein denaturization but excessive cooking results in a lower protein efficiency. His results are shown in the table below.

	Relative protein efficiency. (%)	Relative protein denaturization. (%)	Urease activity (increase in PH)
Control-skim milk	100	-	-
Soybean - raw	30	76.4	1.90
SBM unheated	36	76.2	1.80
SBM mildly heated	70	41.6	0.75
SBM properly cooked	89	14.2	0.20
SBM overcooked	81	5.1	0.05

Raw soybean meal had a P^H rise of approximately 2.0 which falls fairly rapidly as the meal is toasted. A P^H rise of 0.2 during cooking is considered adequate cooking. As the cooking time increases, the meal will eventually record a P^H rise of zero. Since it is impossible to know whether a zero rise in P^H indicates a meal that is perfectly cooked to the point of destroying the urease and antitrypsin enzymes or whether it was overcooked and the proteins damaged, the lower P^H value of 0.05 was included as a check against overcooking. He therefore recommended that a urease value of 0.05 to 0.2 rise could be considered a proper cook in soybean meal.

Caskey and Knapp (1944), as reported by Bird et al. (1947) established a higher criterion that any soybean sample that contained sufficient urease to "cause an increase in the P^H of the solution of one unit" could be considered not adequately heated for feeding. Rackis (1966) on the other hand, suggested a criterion much similar to that of Hayward (1967) that if the urease activity indicated a P^H increase from 0.05 to 0.15, then soybeans could be considered to have been properly processed.

MATERIALS AND METHODS

General

Three feeding trials were conducted. In the first trial, the responses of broiler chicks to graded levels (10, 20 and 30 percent) of boiled and roasted soybeans were determined. In the second study, the effects of supplementing the same levels of soybeans as in the first trial with methionine in broiler diets were determined. The broiler feeding trials were evaluated by measuring the following parameters: growth rate, final weight, feed consumption, feed efficiency, pancreas weight and mortality. Consumer taste panel scores were determined for the second broiler growth study to evaluate the effect of the two soybean meal types on broiler meat quality.

Since the requirements of laying birds differ markedly from those of growing broilers, a third feeding trial was conducted for laying pullets. Three levels each (7.5, 15, and 22.5 percent) of boiled and roasted soybean meals were fed to laying pullets for five 28-day periods. The diets were evaluated by their effects on the following parameters: total egg production, percent hen-day and hen-housed egg production, egg weights, pancreas weights, feed consumption, feed efficiency per dozen eggs, change in body weights and mortality.

Following the feeding trials, four soybean samples (raw soybean, boiled soybean, roasted soybean and the conventional soybean meal 48% protein) were analyzed for urease activity to compare the effectiveness of the heating procedures for processing the various types of soybeans.

Sources and Preparation of the Soybean Meal Ingredients for the Study

The Inari oil roast soybean plant could not supply the quantity of boiled soybeans required for all the feeding trials within a reasonable time. Therefore, it was decided that the total amount of raw soybeans required for the boiled soybean diets be purchased elsewhere and cooked following the cooking procedures of Inari.

About one and a half tons of fresh, 1978 harvested beans of Corsoy soybean variety were purchased for use in this study. The beans were boiled in a steam-jacketed cooker. The cooker was first filled about half way with water and brought to the boiling point. The cooker was then filled to about one third capacity with raw soybeans. The cooking temperature was then maintained at about 90.5°C for 50 minutes following the cooking procedure of Inari. After boiling, the beans were strained to remove excess water. The beans were then spread out in a thin layer on a concrete floor where they were allowed to dry as fast as possible to prevent mold. The dried beans were then ground and stored for later use in the preparation of the cooked soybean diets.

The roasted soybean feed ingredient for these studies was obtained directly from the Inari oil roast soybean plant. The first stage for processing oil roast soybeans involved the same cooking procedure as described for the boiled soybeans except that the product was air dried overnight after straining off the excess water before roasting in deep fat. Condiments like common salt, sodium glutamate, spices etc. may be added. The roasting temperature was about 208°C. The portion of the beans that appear to be overroasted, as judged by their very dark brown color, and the split beans were discarded as wastes. The sediment of condiments that settle at the bottom of the roasting compartment of the machine were also dumped together with overroasts.

It took over one month for the Inari plant to collect sufficient quantity of overroasts for each experiment. During this period, the overroasts were kept covered at room temperature inside the plant during the winter season. This collection time, depending on the temperatures within the plant might be enough to cause oxidative rancidity within any of the supplies of overroasts received from the plant. The storage conditions up to this stage were beyond the control of the researcher. After receiving a supply of overroasts from the plant, it was stored in a cool room with a temperature of 5°C or below before and after grinding for use in feed mixing.

The overroasts were found to be too oily to be ground alone. They were therefore custom-mixed and ground with yellow corn on an equal weight basis. Each batch in the mixer was thoroughly mixed after grinding to obtain a homogeneous mixture. This mixture was then bagged and stored for use in the preparation of roastsoy diets for all the feeding trials.

Experiment I: The effect of boiled and roasted soybean meal diets on broiler chicks

In order to determine the amount of boiled and oil roasted soybeans that could be included in broiler rations with no adverse effects on the growing chicks, three levels each of the two soybean meal types were compared with a control diet in which 48 percent protein, solvent extracted soybean meal (SBM) served as the main source of vegetable protein. There were seven dietary regimens made up as follows:

1. Control diet. SBM 48% protein was the main source of vegetable protein and it contained neither boiled nor roasted soybean meals.

2. Boiled soybean meal (boilsoy) diet, boilsoy at 10% of ration;

3. Boilsoy diet, boilsoy at 20% of ration;

4. Boilsoy diet, boilsoy at 30% ration;

5. Roasted soybean meal (roastsoy) diet, roastsoy at 10% of ration;

6. Roastsoy diet, roastsoy at 20% ration;

7. Roastsoy diet, roastsoy at 30% of ration;

The rations were computer formulated. Non-degummed soybean oil was used to balance the energy levels so as to make all the rations isonitrogenous and isocaloric as much as possible. Despite this, the protein level could not be held constant for the levels of the boilsoy and roastsoy but the amino acid contents expressed as percent of the energy content were kept reasonably constant.

A total of 336 day old Hubbard broiler chicks, 168 of each sex, were wing banded and alloted into 3-gram weight groups. Chicks from each weight class were randomly distributed into each of the 21 floor pens of the brooder house used for the experiment. Each pen measured 4.52 by 1.42 meters. There were 16 chicks, composed of an equal number of each sex, in each pen. By this procedure, average chick weights for all the pens were approximately the same.

Each of the seven experimental diets was fed to three pens of chicks which represented the replicates. The calculated analyses of the diets and the composition of the rations for Experiment I are shown in Table 1.

The chicks were brooded in floor pens using gas fired brooders for space heating and electric heat lamps inside the brooder rings. Two half-gallon chick founts were provided in each pen until about four weeks of age. At that time, each pen was supplied with a mechanical saucer-type

Table 1. Composition of Ingredients in Broiler Rations for Experiment I

Ingredients	SBM Control	Boilsoy Levels 10%	Boilsoy Levels 20%	Boilsoy Levels 30%	Roastsoy Levels 10%	Roastsoy Levels 20%	Roastsoy Levels 30%
Yellow corn, ground	52.41	51.14	49.97	48.71	49.08	45.85	42.52
Soybean (48%)	30.4	22.9	15.4	7.9	24.7	18.9	13.2
Boilsoy, ground	-	10.0	20.0	30.0	-	-	-
Roastsoy, ground	-	-	-	-	10.0	20.0	30.0
Soybean oil	6.1	4.9	3.7	2.5	5.2	4.3	3.5
Salt	.36	.35	.339	.329	.346	.331	.317
Limestone	.60	.60	.50	.492	.60	.60	.50
Dical phosphate	.415	.395	.374	.354	.376	.338	.299
DL-methionine	.216	.216	.216	.217	.197	.178	.159
Constant ingredients[1]	10.5	10.5	10.5	10.5	10.5	10.5	10.5
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analyses							
M.E. K cal/kg	3270	3270	3270	3270	3270	3270	3270
Crude fiber (%)	3.1	3.4	3.7	4.0	3.4	3.7	4.0
Total fat (%)	8.9	9.4	10.0	10.5	9.7	10.4	11.2
Xanthophyll mg/kg	15.69	15.47	15.03	14.81	15.03	14.14	13.48
Crude protein (%)	23.22	23.54	23.87	24.2	23.52	23.83	24.11
Lysine (%)	1.26	1.26	1.26	1.26	1.26	1.26	1.26
Methionine (%)	.56	.56	.55	.55	.55	.53	.52
Methionine & cystine (%)	.92	.92	.92	.92	.92	.92	.92
Tryptophane (%)	.30	.30	.30	.30	.31	.32	.33
Calcium (%)	.92	.92	.92	.92	.92	.92	.92
Available phosphorous (%)	.46	.46	.46	.46	.46	.46	.46
Sodium (%)	.21	.21	.21	.21	.21	.21	.21
Energy-protein ratio	140.9	139.15	136.99	135.12	139.03	137.22	135.46

[1]Constant ingredients--composed as follows: Meat & bone meal, 5%; Distiller's Solubles, 2.5%; Alfalfa (17%), 2.5%; Vitamin--trace mineral premix[2], .5%; Amprol plus, .0125%.
[2]See Table 4.

drinker. Continuous light was provided in the house throughout the experimental period. Feed and water were provided ad libitum. Feed was provided in chick size feed troughs up to three weeks of age. After three weeks, the feed troughs were replaced by hanging feeders, one in each pen.

The chicks were weighed every two weeks and at the end of the feeding trial, which lasted 7.5 weeks. Feed consumption was also determined at the end of every two weeks and at 7.5 weeks. Mortality was recorded as it occurred. In order to determine the effects of the diets on weight of the pancreas, four birds, two of each sex, were randomly selected from each pen at four and 7.5 weeks of age. They were sacrificed, the pancreases were extracted and weighed.

Experiment II: The influence of methionine supplement on the levels of boiled and roasted soybean meals in broiler diets.

Four hundred and forty-eight day-old, Hubbard broiler chicks (equal numbers of each sex) were used for this experiment. The chicks were subdivided into 3-gram weight groups. Chicks from each weight class were randomly distributed into each of the 28 floor pens of the brooder house used for this experiment. There were 16 chicks (eight of each sex) in each pen. Each pen measured 4.52 by 1.42 meters. The average initial weight of the chicks in all the 28 pens was approximately the same. There were 14 dietary regimens as described below:

1. Control diet. Forty-eight percent protein, solvent extracted soybean meal (SBM) was the main source of vegetable protein. It contained neither boiled nor roasted soybean meals. It was supplemented with 0.2% DL-methionine.

2. Same as diet number 1, plus 0.4% supplemental DL-methionine.

3. Boiled soybean meal (boilsoy) at 10% of ration plus 0.2% supplemental DL-methionine.

4. Boilsoy, 10% of ration plus 0.4% supplemental DL-methionine.

5. Boilsoy, 20% of ration plus 0.2% supplemental DL-methionine.

6. Boilsoy, 20% of ration plus 0.4% supplemental DL-methionine.

7. Boilsoy, 30% of ration plus 0.2% supplemental DL-methionine.

8. Boilsoy, 30% of ration plus 0.4% supplemental DL-methionine.

9. Roasted soybean meal (roastsoy), 10% of ration, plus 0.2% supplemental DL-methionine.

10. Roastsoy, 10% of ration plus 0.4% supplemental DL-methionine.

11. Roastsoy, 20% of ration plus 0.2% supplemental DL-methionine.

12. Roastsoy, 20% of ration plus 0.4% supplemental DL-methionine.

13. Roastsoy, 30% of ration plus 0.2% supplemental DL-methionine.

14. Roastsoy, 30% of ration plus 0.4% supplemental DL-methionine.

Each of the 14 experimental diets described above was fed to two replicate pens of chicks. The calculated analyses and the composition of the rations are shown in Table 2.

Table 2. Composition of Ingredients in Broiler Rations for Experiment II

Dietary Regimens	1	2	3	4	5	6	7	8
	Controls		10% Boilsoy		20% Boilsoy		30% Boilsoy	
	Methionine Levels[1]		Methionine Levels		Methionine Levels		Methionine Levels	
Ingredients	.2%	.4%	.2%	.4%	.2%	.4%	.2%	.4%
Yellow corn, ground	47.11	47.31	46.92	47.02	46.53	46.73	46.24	46.44
Soybean meal (48%)	35.1	34.7	26.7	26.3	18.4	18.0	10.0	9.6
Boilsoy, ground	-	-	10.0	10.0	20.0	20.0	30.0	30.0
Roastsoy, ground	-	-	-	-	-	-	-	-
Soybean oil	7.0	7.0	5.6	5.7	4.3	4.3	3.0	3.0
Salt	.39	.39	.38	.38	.37	.37	.36	.36
DL-methionine	.20	.40	.20	.40	.20	.40	.20	.40
Constant ingredients[2]	10.20	10.20	10.20	10.20	10.20	10.20	10.20	10.20
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analyses								
M.E K cal/kg	3270	3270	3270	3270	3270	3270	3270	3270
Crude fiber (%)	3.1	3.1	3.4	3.4	3.7	3.7	4.0	4.0
Total fat (%)	9.4	9.5	9.8	9.9	10.3	10.3	10.7	10.7
Xanthophyll mg/kg	14.8	14.8	14.6	14.8	14.6	14.6	14.6	14.6
Crude protein (%)	24.12	24.12	24.12	24.12	24.24	24.12	24.12	24.12
Lysine (%)	1.35	1.33	1.32	1.31	1.31	1.28	1.27	1.26
Methionine (%)	.56	.75	.55	.74	.54	.74	.55	.73
Methionine & cystine (%)	.93	1.12	.92	1.11	.92	1.10	.92	1.09
Tryptophane (%)	.33	.32	.32	.32	.31	.31	.30	.30
Calcium (%)	.92	.92	.92	.92	.92	.92	.92	.92
Available phosphorous (%)	.46	.46	.46	.46	.46	.46	.46	.46
Sodium (%)	.21	.21	.21	.21	.21	.21	.21	.21
Energy-protein ratio	135.7	135.7	135.7	135.7	134.90	135.7	135.7	135.7

[1] Levels of DL-methionine.

[2] Constant ingredients--composed as follows: Meat & bone meal, 3%; Distiller's Solubles, 2.5%; Alfalfa (17%), 2.5%; Limestone, 0.8%; Dicalcium phosphate, 0.9%; Vitamin--trace mineral premix[3], 0.5%; Amprol plus, .0125%.

[3] See Table 4.

Table 2 (cont'd.)

Dietary Regimens	9	10	11	12	13	14
	10% Roastsoy Methionine Levels[1]		20% Roastsoy Methionine Levels		30% Roastsoy Methionine Levels	
Ingredients	.2%	.4%	.2%	.4%	.2%	.4%
Yellow corn, ground	44.72	44.92	42.43	42.53	40.0	40.15
Soybean Meal (48%)	28.50	28.10	21.90	21.50	15.35	14.90
Boilsoy, ground	-	-	-	-	-	-
Roastsoy, ground	10.00	10.00	20.00	20.00	30.00	30.00
Soybean oil	6.00	6.00	4.90	5.00	3.90	4.00
Salt	.38	.38	.37	.37	.35	.35
DL-methionine	.20	.40	.20	.40	.20	.40
Constant ingredients[2]	10.20	10.20	10.20	10.20	10.20	10.20
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analyses						
M.E K cal/kg	3270	3270	3270	3270	3270	3270
Crude fiber (%)	3.4	3.4	3.7	3.7	4.0	4.0
Total fat (%)	10.1	10.2	10.8	10.8	11.4	11.5
Xanthophyll mg/kg	14.14	14.14	13.70	13.70	13.26	13.26
Crude protein (%)	24.12	24.12	24.12	24.12	24.12	24.12
Lysine (%)	1.32	1.31	1.30	1.29	1.27	1.26
Methionine (%)	.56	.75	.56	.75	.56	.75
Methionine & cystine (%)	.94	1.13	.95	1.14	.96	1.15
Tryptophane (%)	.33	.33	.33	.33	.34	.33
Calcium (%)	.92	.92	.92	.92	.92	.92
Available phosphorus (%)	.46	.46	.46	.46	.46	.46
Sodium (%)	.21	.21	.21	.21	.21	.21
Energy-protein ratio	135.7	135.7	135.7		135.7	135.7

[1]Levels of DL-methionine.

[2]Constant ingredients--composed as follows: Meat & bone meal, 3%; Distiller's Solubles, 2.5%; Alfalfa (17%), 2.5%; Limestone, 0.8%; Dicalcium phosphate, 0.9%; Vitamin-trace mineral premix[3], .50%; Amprol plus, .0125%.

[3]See Table 4.

The chicks were brooded under similar conditions as for Experiment I. The feeding trial lasted five and one-half weeks. Feed and water were provided ad libitum. Continuous light was provided throughout the trial period. Records were kept on the initial weights and final weights of individual birds. Average feed consumption and feed efficiency were determined for each pen.

At the end of the feeding trial, four birds, two of each sex were randomly selected and sacrificed. The pancreases were extracted for pancreas weight determinations. Records of mortality were kept for each pen throughout the experimental period.

Subjective Evaluation of Broiler Meat from Broiler Experiment II by Consumer Taste Panel

At the end of the feeding trial in broiler Experiment II, four birds (two of each sex) from each of the two pens receiving ration 1 (SBM-control diet plus 0.2% supplemental DL-methionine), ration 7 (30% boilsoy diet plus o.2% supplemental DL-methionine), and ration 13 (30% roastsoy diet plus 0.2% supplemental DL-methionine) were randomly selected, slaughtered and processed for sensory evaluation. The objective of this study was to determine the influence of the three soybean meal diets on the broiler meat eating quality. Sensory evaluation of the baked meat was obtained using a consumer-type panel of students and staff from the departments of Food Science and Human Nutrition and Poultry

Science. Two panels were conducted such that broilers of only one sex were evaluated on the panel day.

On each of the two panel days, the dressed birds were halved and wrapped separately in aluminum foil. The birds were then baked in an oven at 177°C (350°F) until they reached an internal temperature of 85°C (185°F). The wrapping was done to prevent the cooking juices and odors from mingling in the oven. No spices, herbs nor salts were added to the baked chicken. The meat was boned prior to serving.

Each panelist was presented with two replicates each of light meat taken from the breast and dark meat taken from the thigh muscles. The panelists were requested to evaluate the meat samples for color, odor, flavor, juiciness, tenderness and overall acceptability using a five point hedonic scale as shown in the scoring key presented below. The broiler meat was finally ranked in order of preference on a three point scale as shown in the scoring key below.

<u>Summary Keys for Taste Panel Scores</u>

<u>Odor, Color and Flavor</u>

5	represents	very desirable
4	"	moderately desirable
3	"	neither desirable nor undesirable
2	"	moderately undesirable
1	"	very undesirable

<u>Juiciness</u>

5	represents	very juicy
4	"	moderately juicy
3	"	neither juicy nor dry
2	"	moderately dry
1	"	very dry

<u>Tenderness</u>

5	represents	very tender
4	"	moderately tender
3	"	neither tender nor tough
2	"	moderately tough
1	"	very tough

<u>Overall Acceptability</u>

5	represents	very acceptable
4	"	moderately acceptable
3	"	neither acceptable nor unacceptable
2	"	moderately unacceptable
1	"	very unacceptable

<u>Overall Ranking</u>

5	represents	most preferred
3	"	middle
1	"	least preferred

For each broiler sex, the results from 15 randomly selected panel participants were tabulated. The data were analyzed using one way analysis of variance with all the parameters of interest regressed for sex as a covariate. Specific mean differences for each parameter were tested using Bonferroni t-statistics.

Experiment III: The effect of boiled and roasted soybean meal diets on performance of laying hens.

Two hundred and twenty-four single comb White Leghorn (SCWL) pullets of two age groups (22 and 26 weeks) were used for this study. The pullets were from the stock of Hannah strain kept at the Michigan State University Poultry Science Research and Teaching Center. The pullets were already with wing bands at the time of this trial.

The birds from each age group were subdivided into 50-gram weight classes discarding the light and heavy birds. The pullets belonging to the same age group and weight class were then allocated at random to 28 stair step cage sections consisting of eight individual bird cages per section. Each individual cage measured 20.3 cm. wide by 40.6 cm. deep by 36 cm. high in front and 45.7 cm. high at the rear. The birds were assigned to the cages so that the birds in similar location of the cage sections were comparable in age and weight class. There was one feed trough for each cage so that all the eight birds within each cage section shared the same feed trough.

There were seven dietary regimens made up as follows:

1. Control diet in which 48% protein, solvent extracted soybean meal (SBM) was the main source of vegetable protein. It contained neither boiled nor roasted soybean meals.

2. Boiled soybean meal (boilsoy) diet, boilsoy at 7.5% ration.

3. Boilsoy diet, boilsoy at 15% of ration.

4. Boilsoy diet, boilsoy at 22.5% ration.

5. Oil roast or roasted soybean meal (roastsoy) diet, at 7.5% of ration.

6. Roastsoy diet, roastsoy at 15% of ration.

7. Roastsoy diet, roastsoy at 22.5% of ration.

The rations were computer formulated. Non-degummed soybean oil was used to balance the energy levels in order to make the rations isonitrogenous and isocaloric. The composition of the rations and the calculated analyses are presented in Table 3.

Each of the seven diets was fed to birds in four of the 28 cage sections. The allocation of the diets to the 28 cage sections was done at random. The four cage sections that received the same type of diet represented the treatment replicates.

The birds were maintained on the treatment diets for three days before data collection started. Feed and water were provided *ad libitum* throughout the feeding trial which consisted of five 28-day periods. The daily light period was maintained at 14 hours throughout the five periods.

Records of the initial and final weights were kept for each individual pullet. Feed consumption was determined for each replicate of eight birds at the end of every 28-day period. Eggs were collected daily and recorded for individual birds. All eggs used for egg weight determinations were held in the cooler overnight and brought to room temperature before the weights were recorded. These eggs were marked to allow specific identification of each egg. Egg weights in grams were determined for individual birds from the mean weights of all the eggs collected from that particular bird over three consecutive days. Records of mortality were kept for each replicate as they occurred.

Hen-housed egg production for each replicate for each period was calculated on the basis of the number of pullets

Table 3. Composition of Ingredients in Broiler Rations for Experiment III

	SBM	Boilsoy Diets			Roastsoy Diets		
		7.5%	15%	22.5%	7.5%	15%	22.5%
Ingredients	Control	Boilsoy	Boilsoy	Boilsoy	Roastsoy	Roastsoy	Roastsoy
Yellow corn, ground	58.05	57.86	57.66	55.21	56.37	54.58	52.7
Soybean (48%)	19.6	13.3	7.0	.70	14.6	9.7	4.8
Boilsoy, ground	-	7.5	15.0	22.5	-	-	-
Roastsoy, ground	-	-	-	-	7.5	15	22.5
Soybean oil	3.3	2.3	1.3	2.55	2.5	1.7	1.0
Salt	.40	.39	.38	.375	.387	.376	.366
DL-methionine	.047	.053	.059	.066	.046	.046	.045
Constant ingredient[1]	19.60	19.60	19.60	19.60	19.60	19.60	19.60
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analyses							
M.E K cal/kg	2961.4	2961.4	2961.4	2961.4	2961.4	2961.4	2961.4
Crude fiber (%)	3.2	3.4	3.6	3.6	3.4	3.6	3.8
Total fat (%)	6.2	6.5	6.8	7.1	6.7	7.2	7.7
Xanthophyll mg/kg	17.0	17.0	15.03	16.8	16.58	16.13	15.85
Crude protein	17.96	17.96	17.96	17.96	17.96	17.96	17.96
Lysine (%)	.92	.90	.88	.87	.90	.89	0.87
Methionine (%)	.32	.32	.32	.32	.32	.32	0.32
Methionine & cystine (%)	.60	.60	.60	.60	.61	.61	0.62
Tryptophan (%)	.23	.22	.22	.21	.23	.24	0.24
Calcium (%)	3.22	3.22	3.22	3.22	3.22	3.22	3.22
Available phosphorous (%)	.50	.50	.50	.50	.50	.50	0.5
Sodium (%)	.21	.21	.21	.21	.21	.21	0.21
Energy-protein ratio	164.9	164.9	164.9	164.9	164.9	164.9	164.9

[1] Constant ingredients--composed as follows: Meat and bone meal, 4%; Alfalfa (17%), 2.5%; Limestone, 6.6%; Dicalcium phosphate, 1.0%; Wheat middlings, 5.0%; Vitamin-trace mineral premix[2], 0.5%.

[2] See Table 4.

housed (8) per replicate. Hen-day egg production was calculated on the basis of the number of pullets present in that replicate for the specific period. Feed consumption was calculated for each replicate as grams of feed per bird per day for each period. Feed efficiency was calculated for each replicate and for each period to obtain the amount of feed in kilograms required to produce a dozen eggs.

At the end of the feeding trial, the first three birds from each cage section (replicate) were sacrificed. The pancreases were extracted for pancreas weight determination. In a few cases where one or two selected cages were found empty, the birds in the fourth and/or the fifth cages were selected to make up the sample size.

Analyses of Soybean Meal Samples for Urease Activity

The urease activity test involved the procedure of Caskey and Knapp (1944) as reported by Bird *et al*. (1947) and the modification for the incubation temperature suggested by Bird *et al*. (1947). This test was done to determine the effectiveness of the amount of heat applied to the various soybeans.

About 50-gram samples were taken from four soybean meal types consisting of the following: 48 percent protein, solvent extracted soybean meal (SBM); raw soybean meal; boiled soybean meal and roasted soybean meal. The samples were ground through a 1 mm screen and were weighed out for the tests.

Table 4. Vitamin-Trace Mineral Premix Used in Mixing the Rations

Micro nutrients	Per lb of Premix Starter-grower	Layer
Vitamin A, U.S.P. units	600,000	800,000
Vitamin D_3, I.C. units	200,000	250,000
Riboflavin, mg	375	700
Pantothenic acid, mg	600	1,200
Niacin, mg.	1,800	2,500
Choline chloride, mg.	40,000	39,000
Folic acid, mg.	-	100
Vitamin B_{12}, mg.	0.9	1.2
Menadione sodium bisulfite, mg.	150.0	150.0
Vitamin E, I.U.	150.0	500.0
Maganese, mg.	1.28	1.287
Iodine, mg.	0.02	0.0201
Copper, mg.	0.08	0.081
Cobalt, mg.	0.005	0.0051
Zinc, mg.	1.00	1.00
Iron, mg.	0.5	0.5025

Used at the rate of 10 lbs per ton.

Statistical Procedures

The analysis common to all the experiments was the analysis of variance (ANOVA) using the Statistical Package for the Social Sciences (SPSS). Pen averages were used for the two broiler experiments. For the layer experiment, individual bird data for each of the five 28-day periods for egg number, egg weight, and weight gain (for last period only) and the replicate mean data values for each of the five 28-day periods for hen-day egg production, hen-housed egg production, feed consumption, feed efficiency per dozen eggs, mortality and pancreas weight (for last period only) were used in the statistical analyses.

The ANOVA for the first broiler and the layer feeding trials employed a split plot analysis as described by Gill (1978). In the first broiler and the layer feeding trials, the whole plot was represented by replicate within level of soybean meal within type of soybean while the sub plot was represented by period. The second broiler feeding trial involved a pseudo factorial treatment design with three factors, namely, type of soybean meal, level of soybean meal, and methionine level.

To compute the ANOVA with the data for the feeding experiments, the sources of variation were grouped into various models for each trial as illustrated below:

<u>Broiler I</u> - consisted of two models

Model 1 - for Level within Treatment (Level/Trt)

Model 2 - for Treatment, Replicate and Period.

<u>Broiler II</u> - consisted of two models

Model 1 - for Level within Treatment (Level/Trt)

Model 2 - for Treatment, Replicate and Methionine

<u>Layer experiment</u> - consisted of five models

Model 1 - for Level within Treatment (Level/Trt), Level/Trt x Replicate (Rep).

Model 2 - for Level/Trt x Period.

Model 3 - for Level/Trt x Bird, Body weight.

Model 4 - for Bird, Treatment x Bird, Replicate x Bird.

Model 5 - for Treatment, Replicate, Treatment x Replicate, Period, Treatment x Period, Period x Treatment x Replicate.

Treatment x Replicate mean squares were tested against Level/Trt x Rep mean squares at $p < 0.25$. If this test was significant, then Treatment x Replicate mean square (called error a1) was used to test Treatment for significance while Level/Trt x Rep (called error a2) was used to test Level/Trt. If, on the other hand, the above test at $p < 0.25$ was found to be non-significant, then the "error a" term was computed by pooling Treatment x Replicate and Level/Trt x Replicate mean squares and this was used to test for the significance of Treatment and Level/Trt. The "error b" term was used to test all other sources of variation besides Treatment and Level/Trt for significance.

The "error b" SS (or simply residual SS) and the associated degrees of freedom were computed as follows:

<u>Broiler I</u>

Error b SS = Total SS (model 2) minus
Explained SS (model 2)
Level/Trt SS (model 1)
Level/Trt x Rep SS (model 1)
Level/Trt x Period SS (model 1)
Level/Trt x Rep x Period SS (model 1)

Degrees of Freedom for Error b (DFb)

DFb = Total DF (model 2) minus
Explained df (model 2)
Level/Trt df (model 1)
Level/Trt x Rep df (model 1)
Level/Trt x Period df (model 1)
Level/Trt x Rep x Period df (model 1)

Broiler II

Error b SS = Total SS (model 2) minus
Explained SS (model 2)
Level/Trt SS (model 1)
Level/Trt x Rep SS (model 1)

Degrees of Freedom for Error b (DFb)

DFb = Total df (model 2) minus
Explained df (model 2)
Level/Trt df (model 1)
Level/Trt x Rep df (model 1)

Layer experiment

Error b SS = Total SS (model 5) minus
Explained SS (model 5)
Level/Trt SS (model 1)
Level/Trt x Rep SS (model 1)
Level/Trt x Period SS (model 2)
Bird SS (model 4)
Treatment x Bird SS (model 4)
Replicate x Bird SS (model 4)
Level/Trt x Bird SS (model 3)
Body weight SS (model 3)

Degrees of Freedom for Error b (DFb)

DFb = Total df (model 5) minus
Explained df (model 5)
Level/Trt df (model 1)
Level/Trt x Rep df (model 1)
Level/Trt x Period df (model 2)
Bird df (model 4)
Treatment x Bird df (model 4)
Rep x Bird df (model 4)
Level/Trt x Bird df (model 3)
Body weight df (model 3)

The taste panel scores for broiler meat qualities and the urease analysis data were analyzed by the simple one-way ANOVA.

Further tests beyond the ANOVA for all the experiments employed the Bonferroni t-statistics to determine the specific differences between means.

In those cases where the effects of soybean meal levels were examined, all linear and quadratic effects were computed as described by Gill (1978). The square root of the variance divided by the number of observations per mean was used as the standard error of mean.

For each parameter discussed with a statistical analysis, the ANOVA tables are provided in Appendices A to F. The 0.01 and 0.05 levels of probability provided the basis for all statements concerning statistically significant differences. The experimental designs for the feeding trials are illustrated in Figures 1 to 3.

Soy-type	Soybean Levels (%)	Replicates
SBM-control diet	30	1
		2
		3
Boiled soybean meal diets	10	
	20	
	30	
Roasted soybean meal diets	10	
	20	
	30	

Figure 1. Design for Broiler Experiment I.

Soy-type	Soybean Levels (%)	Supplementary Methionine Levels (%)	Replicates
SBM-control diet	35	0.2	1 2
		0.4	
Boiled soybean meal diets	10	0.2	
		0.4	
	20	0.2	
		0.4	
	30	0.2	
		0.4	
Roasted soybean meal diets	10	0.2	
		0.4	
	20	0.2	
		0.4	
	30	0.2	
		0.4	

Figure 2. Design for Broiler Experiment II

Soy-type	Soybean Levels (%)	Replicates
SBM-control diet	19.5	1
		2
		3
		4
Boiled soybean meal diets	7.5	
	15.0	
	22.5	
Roasted soybean meal diets	7.5	
	15.0	
	22.5	

Figure 3. Design for Layer Experiment III

RESULTS AND DISCUSSION

Experiment I: Broiler Feeding Experiment

<u>Treatment Effects</u>

Treatment in this study refers to the types of soybean meal diets fed. These include 48% protein soybean meal (SBM) diet, boiled soybean meal (boilsoy) diet and roasted soybean meal (roastsoy) diet. The analyses of variance of the data for final weights, body weight gain, feed consumption, feed conversion, pancreas weights and mortality are presented in Appendix Tables A-1 to A-6, respectively. These tables show that treatment had no significant influence on the birds for all the parameters examined.

Table 5 shows the response of broiler chicks to boiled and roasted soybean meal diets for both sexes. The values of the boilsoy and the roastsoy diets for each of the parameters shown represented the means for the groups of birds fed each of the three levels of boilsoy or each of the three levels of roastsoy diets, respectively.

Comparison of mean values also indicated no significant difference between the birds fed the SBM (control), the boilsoy and the roastsoy diets for all the parameters studied except body weight gain. In this case, the birds fed the boilsoy diets had a significantly larger weight gain

Table 5. Response of Broiler Chicks to Boiled and Roasted Soybean Meal Diets Fed for 7.5 Weeks (Results for Both Sexes Combined)

	Final weights (gms)		Weight gain (gms)	Pancreas Weights (gms)		Feed consumption (gms/bird)		Feed conversion (gms feed/gms gain)		Mortality		
	Means	±SE	Means	Means	±SE	Mean	±SE	Mean	±SE	Mean %	±SE	Actual Dead
SBM (control) Diet	2165.45^{a}	271.8	2127.96^{ab}	3.68^{a}	0.62	4141.04^{a}	46.1	1.95^{a}	.032	6.25^{a}	2.08	3/48
Boilsoy Diets	2191.35^{a}	214.6	2153.69^{a}	3.74^{a}	0.43	4097.91^{a}	188.7	1.90^{a}	.045	4.86^{a}	0.58	7/144
Roastsoy Diets	2131.71^{a}	213.8	2094.20^{b}	3.84^{a}	0.59	4046.99^{a}	156.6	1.93^{a}	.043	4.86^{a}	0.47	7/144

Means with the same letter superscript do not differ significantly at 0.05 level of probability.

($p < 0.05$) than the birds fed roastsoy diets. The birds fed the boilsoy diet had a slightly larger weight gain value than the SBM (control) diet although the difference was not significant. There was also no significant difference in body weight gain values between the birds fed the roastsoy and those fed the SBM (control) diet. When the sexes were separated as shown in Tables 6 and 7, there were no significant differences in the mean values for pancreas weights, final weights and weight gains between the birds fed the SBM (control) diet and either the boilsoy or the roastsoy diets.

<u>Effect of Soybean Meal Levels</u>

Soybean meal levels for this trial were 10, 20 and 30 percent of the ration for the boilsoy and roastsoy diets. The ANOVA presented in Tables A-1 to A-6 (Appendix A) also indicated that levels of soybean meals had no significant influence on the performance of broilers for final weight, body weight gain, feed consumption, feed conversion, pancreas weights and mortality.

Tables 8 and 9 show the effect of levels of boiled and roasted soybean meals, respectively, in broiler diets on the response of birds for pancreas weight, final body weight gain, feed consumption, feed conversion and mortality. Comparisons of means of the birds fed SBM (control) diet with those fed any of the three boilsoy levels

Table 6. Response of Broiler Chicks to Boiled and Roasted Soybean Meal Diets Fed for 7.5 Weeks (Results for Males)

	Pancreas Weight (gms) Mean	±SE	Final weights (gms) Mean	±SE	Weight gain (gms) Mean
SBM (control) Diet	3.93[a]	.48	2409.06[a]	27.4	2371.49[a]
Boilsoy Diets	4.04[a]	.78	2372.63[a]	106.8	2335.96[a]
Roastsoy Diets	4.22[a]	.56	2318.44[a]	118.4	2281.82[a]

Means with the same letter superscript do not differ significantly at 0.05 level of probability.

Table 7. Response of Broiler Chicks to Boiled and Roasted Soybean Meal Diets Fed for 7.5 Weeks (Results for Females)

	Pancreas Weight (gms) Mean	±SE	Final weights (gms) Mean	±SE	Weight gain (gms) Mean
SBM (control) Diet	3.43[a]	.73	1921.83[a]	77.2	1883.41[a]
Boilsoy Diets	3.44[a]	.72	2010.87[a]	218.7	1971.43[a]
Roastsoy Diets	3.46[a]	.30	1944.98[a]	69.7	1906.56[a]

Means with the same letter superscript do not differ significantly at 0.05 level of probability.

(Table 8) show no significant difference for all the parameters studied. There was also no significant difference between the birds fed the control diet and those fed any of the three roastsoy levels for pancreas weights, final body weights, feed conversion and mortality but there were, however, significant differences in these groups of birds for body weight gain and feed consumption (Table 9). Birds fed the 10% roastsoy diet had significantly faster gain than those birds fed the 20% roastsoy diet ($p < 0.05$) but not significantly faster than those birds fed either the 30% roastsoy diet or the SBM (control) diet. Body weight gain for the birds fed the control diet was not significantly higher than the values for any of the three roastsoy levels.

Similarly, feed consumption was higher for the birds that consumed the 10% roastsoy diet ($p < 0.05$) than for those birds fed the 20% roastsoy diet but not significantly higher than the consumption of the birds fed the 30% roastsoy diet or than the consumption of those fed the SBM (control) diet. In fact, the amount of feed consumed by the birds visually correlated very well with the values for their body weight gain. Feed consumption by the birds fed the SBM (control) diet was not significantly different from those fed the 10% or the 30% roastsoy diets but was higher than that of the birds fed the 20% roastsoy diet at 0.05 level of probability.

Table 8. Effect of Levels of Boiled Soybean Meal in Broiler Diets Fed for 7.5 Weeks

	Pancreas Weight (gms)		Final weights (gms)		Weight gain (gms)	Feed consumption (gms/bird)		Feed conversion (gms feed/gms gain)		Mortality		
	Mean	±SE	Mean	±SE	Mean	Mean	±SE	Mean	±SE	Mean %	±SE	Actual Dead
SBM (control) Diet	3.68[a]	.62	2165.45[a]	271.8	2127.96[a]	4141.04[a]	46.1	1.95[a]	.032	6.25[a]	2.08	3/48
10% Boilsoy Diet	3.87[a]	.45	2169.25[a]	204.8	2131.64[a]	4162.83[a]	147.3	1.94[a]	.012	4.17[a]	2.40	2/48
20% Boilsoy Diet	3.78[a]	.44	2212.22[a]	260.2	2174.68[a]	4106.88[a]	315.1	1.89[a]	.021	4.17[a]	1.21	2/48
30% Boilsoy Diet	3.57[a]	.41	2192.58[a]	214.2	2154.76[a]	4024.02[a]	82.7	1.87[a]	.051	6.25[a]	2.08	3/48

Means with the same letter superscript do not differ significantly at 0.05 level of probability.

Table 9. Effect of Levels of Roasted Soybean Meal in Broiler Diets Fed for 7.5 Weeks

	Pancreas Weight (gms)		Final weights (gms)		Weight gain (gms)	Feed consumption (gms/bird)		Feed conversion (gms Feed/gms gain)		Mortality		
	Mean	±SE	Mean	±SE	Mean	Mean	±SE	Mean	± SE	Mean %	±SE	Actual Dead
SBM (control) Diet	3.68^{a}	.62	2165.45^{a}	271.8	2127.96^{ab}	4141.04^{a}	46.1	1.95^{a}	.032	6.25^{a}	2.08	3/48
10% Roastsoy Diet	4.11^{a}	.71	2208.45^{a}	234.0	2170.76^{a}	4220.80^{a}	103.6	1.94^{a}	.055	6.25^{a}	1.21	3/48
20% Roastsoy Diet	3.73^{a}	.35	2057.33^{a}	147.9	2020.03^{b}	3932.25^{b}	102.7	1.95^{a}	.027	4.16^{a}	1.21	2/48
30% Roastsoy Diet	3.68^{a}	.64	2129.36^{a}	255.0	2091.80^{ab}	3987.92^{ab}	80.5	1.91^{a}	.029	4.16^{a}	1.21	2/48

Means with the same letter superscript do not differ significantly at 0.05 level of probability.

Influence of Sex

The analysis of variance shows that sex of the birds had a highly significant influence ($p < 0.01$) on the birds' final body weights and body weight gain (see Appendices Tables A-1 and A-2), but not for pancreas weights (Appendix Table A-5). Comparisons of treatment means for the birds' final body weights and body weight gain presented in Table 10 also confirmed this by showing males to be consistently heavier ($p < 0.01$) than the females for all the types of soybean meals fed. For the boilsoy and the roastsoy diets, the differences in pancreas weights between the sexes were highly significant ($p < 0.01$) with males having the larger pancreases. The males from the group of birds fed the SBM (control) diet also had larger pancreases than the females but the differences were not significant.

Effect of Periods

As expected, the ANOVA for broiler data presented in Tables of Appendix A-1 to A-6 showed that periods had a highly significant influence ($p < 0.01$) on the birds response for final body weight, body weight gain, feed consumption, feed conversion, pancreas weight and mortality. The mean response values of the birds to the seven diets by periods for final body weights, feed consumption, feed conversion, pancreas weights and mortality are presented in Appendix Tables F-1 to F-5. Table of Appendix F-5 for mortality, indicates more than 70 percent of the mortality

Table 10. Response by Sex of Broiler Chicks to Boiled and Roasted Soybean Meal Diets Fed for 7.5 Weeks

	Pancreas Weight (gms) Mean	$\pm$SE	Final weights (gms) Mean	$\pm$SE	Weight gain (gms) Mean
SBM (control) Diet					
Both sexes	3.68^{a}	.62	2165.45^{ab}	271.8	2127.96^{b}
Males	3.93^{a}	.48	2409.06^{a}	27.4	2372.49^{a}
Females	3.43^{a}	.73	1921.83^{b}	77.2	1883.41^{c}
Boilsoy Diets					
Both sexes	3.74^{ab}	.43	2191.35^{ab}	214.6	2153.69^{b}
Males	4.04^{a}	.78	2372.63^{a}	106.8	2335.96^{a}
Females	3.44^{b}	.72	2010.87^{b}	218.7	1971.43^{c}
Roastsoy Diet					
Both sexes	3.84^{a}	.59	2131.71^{ab}	213.8	2094.20^{b}
Males	4.22^{a}	.56	2318.44^{a}	118.4	2281.82^{a}
Females	3.46^{b}	.30	1944.98^{b}	69.7	1906.56^{c}

Within each type of soybean meal diet, means having the same letter superscripts are not significantly different while means not having the same letter superscripts are significantly different at the .01 level of probability.

occurred between the third and the fourth periods. This result could be related to similar observations made for both broiler feeding trials. In each case, beginning from the third week, many chicks from all the pens began to develop swollen hocks. This eventually resulted in lameness and hence starvation due to inability of the affected chicks to reach the feeders and waterers. This condition seemed to be aggravated by the periodic handling of the birds for weighing because the condition was less serious in the second broiler feeding trial where the birds were handled for weighing only at the beginning and at the end of the trial. Most of the mortality recorded after the second period was found to be related to this problem. Some of the affected chicks were sent to Michigan State University's Animal Health Diagnostic laboratory for examination and post mortem. The reports could not relate the cause of this condition to the experimental diets. This condition was not observed during the feeding trial with laying hens.

Experiment II: Broiler Feeding Experiment

Treatment Effects

Treatment in this trial refers to the three types of soybean meals (SBM, boilsoy and roastsoy). The ANOVA of the broiler data for final body weight, body weight gain, feed consumption, feed conversion, pancreas weights and mortality are presented in the Appendices Tables B-1 to B-6, respectively. The ANOVA tables indicate no significant effect of treatment on the response of birds for all the parameters studied.

Table 11 shows the response of broiler chicks to boiled and roasted soybean meal diets for both sexes. The values of the boilsoy or the roastsoy diets for all the parameters represented the mean values for all the birds fed the three levels of either the boilsoy or the roastsoy diets. The comparison of the treatment means of the birds' response to the various parameters shown in Table 11 indicated significant differences between the groups of birds fed the different soybean meals for final body weights, body weight gain, feed consumption and feed conversion. There were no significant differences between the three groups of birds for pancreas weights and percent mortality.

Table 11 also indicates SBM (control) diet supported the production of birds with significantly ($p < 0.05$) larger final body weights than the boilsoy diets but not significantly larger than those birds fed the roastsoy diets. There was no significant difference between the final body weights of the birds fed the boilsoy diets and those fed the roastsoy diets. The final body weight treatment means and the standard errors were 1462.6 ± 142.52 for the control diet, 1413.87 ± 142.39 for roastsoy diets and 1377.35 ± 124.73 for boilsoy diets, respectively.

Table 11. Response of Broiler Chicks to Boiled and Roasted Soybean Meal Diets Fed for 5.5 Weeks (Results for Both Sexes Combined)

	Pancreas Weight (gms) Mean	Final weights (gms) Mean	Weight gain (gms) Mean	Feed consumption (gms/bird) Mean	Feed conversion (gms feed/gms gain) Mean	Mortality Mean %	Mortality Actual Dead
SBM (control) Diet	3.80^{a}	1462.60^{a}	1422.63^{a}	2416.6^{Aa}	1.71^{ab}	6.25^{a}	4/64
±SE	.59	142.52	138.94	90.7	.051	1.28	
Boilsoy Diets	3.84^{a}	1377.35^{b}	1341.76^{b}	2330.2^{ABb}	1.74^{b}	1.56^{a}	3/192
±SE	.47	124.73	124.69	89.4	.047	.084	
Roastsoy Diets	3.67^{a}	1413.87^{ab}	1378.91^{ab}	2301.1^{Bb}	1.68^{a}	2.08^{a}	4/192
±SE	.40	142.39	142.35	90.9	.029	0.52	

Means having common capital or small letter superscripts are not significantly different while means not having common letters are significantly different at the .01 and .05 levels of probability, respectively.

The comparisons of treatment means for body weight gain were quite similar to those described for final body weights. The control diets also supported significantly faster gain (1422.63 gms ± 138.94 gms) than the value of 1341.76 ± 124.69 grams obtained for the birds fed the boilsoy diets ($p < 0.05$). Again there was no significant difference between the birds fed the control diet and the birds fed the roastsoy diets with a mean weight of 1378.91 ± 142.35 grams. There was also no significant difference between the birds fed the boilsoy diets and those birds fed the roastsoy diets for body weight gain.

In the case of feed consumption, Table 11 also indicated that the birds fed the SBM (control) diet consumed considerably more feed (2416.56 ± 90.66 grams) than either those birds fed the boilsoy diets (2330.25 ± 89.4 grams) ($p < 0.05$), or those fed the roastsoy diets (2301.14 ± 90.91 grams) ($p < 0.01$). Again, there was no significant difference in the feed consumption between the birds fed either the boilsoy or the roastsoy diets.

The birds fed the roastsoy diets had a significantly better feed conversion than those birds fed the boilsoy diets ($p < 0.05$). All the birds fed the roastsoy diets had a feed to gain ratio of 1.68 ± 0.029 versus a ratio of 1.74 ± 0.047 for all the birds fed the boilsoy diets. There were no significant differences between the birds fed the SBM (control) diet with a feed to gain ratio of 1.71 ± 0.051

and the feed to gain ratio of either the birds fed the boilsoy or the roastsoy diets.

Tables 12 and 13 show the response of broiler chicks to boiled and roasted soybean meal diets for males and females, respectively. There were no significant differences in the pancreas weights between the birds fed the SBM (control) diet and those birds fed the boilsoy or the roastsoy diet when the sexes were separated. Table 12, however, indicated highly significant differences ($p < 0.01$), in the final body weights and body weight gains between the males fed the SBM (control) diet and those fed the boilsoy diets. Again, for the males (Table 12), there were no significant differences in the final body weights and body weight gains between the birds fed SBM (control) diet and the mean for the group of birds fed the roastsoy diets. For the females only (Table 13), the birds fed the SBM (control) diet had a significantly higher final body weight and body weight gain than either those birds fed the boilsoy or those fed the roastsoy diets at the 0.05 level of probability but there were no significant differences in these two parameters between the birds fed the boilsoy and those fed the roastsoy diets.

Effect of Soybean Meal Levels

Levels of soybean meals for this trial were 10, 20 and 30 percent of the ration for the boilsoy and roastsoy

Table 12. Response of Broiler Chicks to Boiled and Roasted Soybean Meal Diets Fed for 5.5 Weeks (Results for Males)

	Pancreas Weight (gms)		Final weights (gms)		Weight gain (gms)	
	Mean	±SE	Mean	±SE	Mean	±SE
SBM (control) Diet	4.18[a]	.30	1590.00[a]	62.4	1545.08[a]	62.4
Boilsoy Diets	4.05[a]	.49	1489.83[b]	59.32	1454.19[b]	59.18
Roastsoy Diets	3.82[a]	.34	1543.78[ab]	36.95	1508.84[ab]	40.38

Means with the same letter superscript are not significantly different while means not having the same letter superscript are significantly different at the .01 level of probability.

Table 13. Response of Broiler Chicks to Boiled and Roasted Soybean Meal Diets Fed for 5.5 Weeks (Results for Females)

	Pancreas Weight (gms)		Final weights (gms)		Weight gain (gms)	
	Mean	±SE	Mean	±SE	Mean	± SE
SBM (control) Diet	3.41[a]	.30	1335.19[a]	20.60	1300.18[a]	20.88
Boilsoy Diets	3.62[a]	.26	1264.88[b]	7.45	1229.33[b]	7.33
Roastsoy Diets	3.51[a]	.26	1283.95[b]	45.51	1248.99[b]	45.52

Means with the same letter superscript are not significantly different while means not having the same letter superscript are significantly different at the 0.05 level of probability.

diets. There was only one level for the SBM (control) diet which was the percentage amount supplying the total oil seed meal protein of the control ration. Tables 14 and 15 show the effect of levels of boiled soybean meal and roasted soybean meal respectively, in broiler diets. Each mean value shown along the same row, for each diet for the six parameters presented in each table represents the mean of the birds fed each of the two levels of supplementary methionine (0.2 and 0.4 percent supplementary DL-methionine).

The ANOVA results presented in Appendix Tables B-1 to B-6 showed that the levels of the boilsoy and roastsoy had no significant influence on the response of broiler chicks for final body weight, feed consumption, feed conversion, pancreas weights and rate of mortality, but the levels had a significant influence on the body weight gain at 0.05 level of probability.

Table 14 indicated no significant differences between the groups of birds fed any of the boilsoy levels (10, 20 and 30 percent), for pancreas weights, feed conversion and mortality rate. It could also be observed from the same table that as the levels of boilsoy increased, the final body weight and body weight gain decreased. The birds fed the SBM (control) diet had a mean final body weight of 1462.60 $\pm$ 142.54 grams which was not significantly different from a mean final body weight value of 1412.69 $\pm$ 161.71 grams for the birds fed the 10% boilsoy diet. The birds that consumed the SBM (control) diet, however, had significantly larger final body weight at the 0.01 level of probability than those groups of birds that consumed either the 20 or 30 percent boilsoy diets. There were no significant differences in the final body weights between the birds fed either 10, 20 or 30 percent boilsoy diets.

For body weight gain, Table 14 showed no significant difference between the birds that consumed the SBM (control) diet and those that consumed the 10% boilsoy diet but the birds that consumed the control diet had significantly higher body weight gain than those birds that consumed either the 20 or 30 percent boilsoy diets ($p < 0.01$). There were no significant differences for body weight gain between the birds that consumed either the 10 or 20 percent boilsoy diets or between those that consumed either the 20 or 30 percent boilsoy diets.

Orthogonal polynomial tests for final weight and weight gain indicated a linear weight decline as the level of boilsoy increased. Only body weight gain was significant quadratically which suggests that the decrease was not at a uniform rate over the range of boilsoy levels studied.

Feed consumption was not significantly different between the birds fed the control diet with a mean value of 2416.56 $\pm$ 90.66 grams and that of the birds fed the 10% boilsoy diet with a mean feed consumption of 2419.32 $\pm$ 51.24 grams. The birds that were fed either the 20% boilsoy diet,

Table 14. Effect of Levels of Boiled Soybean Meal in Broiler Diets Fed for 5.5 Weeks

	Pancreas Weight (gms) Mean	Final weights (gms) Mean	Weight gain (gms) Mean	Feed consumption (gms/bird) Mean	Feed conversion (gms feed/gms gain) Mean	Mortality Mean %	Mortality Actual Dead
SBM (control) Diet	3.80^{a}	1462.60^{a}	1422.63^{a}	2416.56^{a}	1.71^{a}	6.25^{a}	4/64
$\pm$SE	.59	142.54	138.90	90.66	.051	1.28	
10% Boilsoy Diet	4.02^{a}	1412.69^{ab}	1377.08^{ab}	2419.32^{a}	1.76^{a}	3.13^{a}	2/64
$\pm$SE	.53	161.71	161.53	51.24	.048	1.41	
20% Boilsoy Diet	3.64^{a}	1367.93^{b}	1332.43^{bc}	2273.32^{b}	1.71^{a}	0.00^{a}	0/64
$\pm$SE	.15	117.94	118.00	66.33	.033	0.00	
30% Boilsoy Diet	3.86^{a}	1351.44^{b}	1315.77^{c}	2298.13^{b}	1.75^{a}	3.13^{a}	2/64
$\pm$SE	.59	93.60	101.37	82.53	.054	0.71	

Means with the same letter superscript do not differ significantly at 0.01 level of probability.

however, consumed significantly less feed ($p < 0.01$) than those birds fed the SBM (control) diet or the 10% boilsoy diet. Again, there was no significant difference between the feed consumption of the birds fed the 20% boilsoy and those fed the 30% boilsoy diets which had the values of 2272.32 $\pm$ 66.23 grams and 2298.13 + 82.53 grams, respectively.

The effects of levels of roasted soybean meal in broiler diets are presented in Table 15. This table indicates no significant differences in the response of broiler chicks between the birds fed the SBM (control) diet and any of the groups of birds fed either the 10, 20, or 30 percent roastsoy for pancreas weights, body weight gain, feed conversion and the mortality rate. There were also no significant differences in the response of the birds between the three roastsoy levels for those parameters mentioned. For final body weight, the birds fed the SBM (control) diet were not significantly different from those birds fed either the 10 or 20 percent roastsoy diets but had a significantly higher mean final body weight than those birds fed the 30% roastsoy ($p < 0.05$). Although there were no significant differences in the final body weight values between the groups of birds fed any of the three roastsoy dietary levels, the optimum level of roastsoy in broiler diets for maximum response was found by regression to be 25%.

Table 15. Effect of Levels of Roasted Soybean Meal in Broiler Diets Fed for 5.5 Weeks

	Pancreas Weight (gms) Mean	Final weights (gms) Mean	Weight gain (gms) Mean	Feed consumption (gms/bird) Mean	Feed conversion (gms feed/gms gain) Mean	Mortality Mean %	Mortality Actual Dead
SBM (control)							
Diet	3.80^{a}	1462.60^{a}	1422.63^{a}	2416.6^{Aa}	1.71^{a}	6.25^{a}	4/64
±SE	.59	142.54	138.9	90.7	.051	1.28	
10% Roastsoy							
Diet	3.59^{a}	1421.84^{ab}	1385.85^{a}	2315.1^{ABb}	1.68^{a}	1.56^{a}	1/64
±SE	.39	147.51	147.2	9.9	.030	.78	
20% Roastsoy							
Diet	3.85^{a}	1422.12^{ab}	1387.11^{a}	2302.4^{Bb}	1.66^{a}	1.56^{a}	1/64
±SE	.36	147.95	147.0	101.8	.038	.78	
30% Roastsoy							
Diet	3.57^{a}	1397.65^{b}	1363.78^{a}	2286.2^{Bb}	1.69^{a}	3.13^{a}	2/64
±SE	.43	150.76	141.4	141.9	.022	.90	

Means having common capital or small letter superscripts are not significantly different while means not having common letter superscripts are significantly different at the .01 and .05 levels of probability, respectively.

The feed consumed by the birds fed the SBM (control) diet was significantly higher than the amount consumed by either those fed the 10% roastsoy diet ($p < 0.05$), the 20% roastsoy diet ($p < 0.01$), or the 30% roastsoy diet ($p < 0.01$). There were no significant differences in the amount of feed consumed by the birds fed either the 10, 20 or 30 percent roastsoy diets.

Effects of Levels of Methionine

The ANOVA tables presented in Appendices B-1 to B-6 show that methionine supplementation to the three types of soybean meal broiler diets had no significant influence on the response of broiler chicks to final body weight, feed consumption, feed conversion and mortality rate. The influence of methionine supplementation was significant only for the response of broiler chicks to body weight gain and pancreas weights, both at 0.05 level of probability. Table 16 shows the response of broiler chicks to supplementary methionine levels in boiled and roasted soybean meal diets fed for 5 1/2 weeks. The two supplementary methionine levels (0.2 and 0.4 percent) for each type of soybean meal were compared in this table. The table revealed no significant differences in the response of the broiler chicks for all the parameters studied when the diets were supplemented with either 0.2% or 0.4% DL-methionine for any of the groups fed any of the diets.

Table 16. The Results of Feeding Boiled and Roasted Soybean Meal Broiler Diets Supplemented with Methionine

	Pancreas Weight (gms) Mean	Final weights (gms) Mean	Weight gain (gms) Mean	Feed consumption (gms/bird) Mean	Feed conversion (gms feed/gms gain) Mean	Mortality Mean %	Mortality Actual Dead
SBM (control) Diets							
0.2% Meth.	4.01^{a}	1491.97^{a}	1456.49^{a}	2457.71^{a}	1.70^{a}	3.13^{a}	1/32
+SE	.56	166.57	165.9	22.39	.021	2.21	
0.4% Meth.	3.59^{a}	1433.22^{a}	1388.77^{a}	2375.41^{a}	1.71^{a}	9.38^{a}	3/32
±SE	.61	131.76	120.2	131.84	.085	6.63	
Boilsoy Diets							
0.2% Meth.	4.02^{a}	1376.75^{a}	1341.08^{a}	2372.19^{a}	1.77^{a}	2.08^{a}	2/96
+SE	.46	122.04	122.2	75.11	.032	0.54	
0.4% Meth.	3.66^{a}	1377.95^{a}	1342.44^{a}	2288.32^{a}	1.70^{a}	0.00^{a}	0/96
±SE	.44	132.80	132.5	87.87	0.34	0.00	
Roastsoy Diets							
0.2% Meth.	3.84^{a}	1429.86^{a}	1394.55^{a}	2337.12^{a}	1.68^{a}	2.08^{a}	2/96
±SE	.24	143.33	143.4	87.65	.037	0.54	
0.4% Meth.	3.51	1397.88^{a}	1363.27^{a}	2265.17^{a}	1.67^{a}	2.08^{a}	2/96
±SE	.46	145.93	145.8	85.99	.020	0.54	

Within each type of soybean meal diet, means with the same letter superscript do not differ significantly at 0.05 level of probability.

Influence of Broiler Sex on Response to Boiled Soybean and Roasted Soybean Meal Diets

The ANOVA tables in Appendices B-1, B-2 and B-5 indicate that sex of broiler chicks had a highly significant influence on the birds' final body weight and body weight gain ($p < 0.01$), but had no significant influence on the pancreas weights.

Table 17 shows the response of broiler chicks by sex to boiled and roasted soybean meal diets fed for 5 1/2 weeks. The table shows the comparisons of mean values of both sexes together and separated for each type of soybean meal (SBM, boilsoy and roastsoy) diets, and for the following parameters--pancreas weights, final body weights and body weight gain. According to this table, there were no significant differences in the pancreas weights between the sexes whether separated or combined for any of the SBM, boilsoy or roastsoy diets. As for the body weight gain and for final body weights, the male birds had consistently larger values ($p < 0.05$) than the females. These observations were quite similar to those made in the first broiler feeding trial.

Summary, Results and Discussion of Broiler Experiments I and II

The results of the two broiler feeding trials agreed in that the birds fed either the SBM (control), the boilsoy or the roastsoy diets indicated no significant differences

Table 17. Response of Broilers by Sex to Boiled and Roasted Soybean Meal Diets Fed for 5.5 Weeks

	Pancreas Weight (gms) Mean	$\pm$SE	Final weights (gms) Mean	$\pm$SE	Weight gain (gms) Mean	$\pm$SE
SBM (control) Diets						
Both sexes	3.80[a]	.59	1462.60[a]	142.52	1422.63[b]	138.94
Males	4.18[a]	.30	1590.00[a]	62.4	1545.08[a]	74.89
Females	3.41[a]	.30	1335.19[c]	20.69	1300.18[c]	20.88
Boilsoy Diets						
Both sexes	3.84[a]	.47	1377.35[b]	124.73	1341.76[b]	24.69
Males	4.05[a]	.49	1489.83[a]	59.32	1454.19[a]	59.18
Females	3.62[a]	.26	1264.88[c]	7.45	1229.33[c]	7.33
Roastsoy Diets						
Both sexes	3.67[a]	.40	1413.87[b]	142.39	1378.91[b]	142.35
Males	3.82[a]	.34	1543.78[a]	36.95	1508.84[a]	40.38
Females	3.51[a]	.26	1283.95[c]	45.51	1248.99[c]	45.52

Within each type of soybean meal diets, means with the same letter superscript do not differ significantly at 0.01 level of probability.

for pancreas weights and rate of mortality. The two results differ, however, with respect to the response of the birds to the three types of soybean meals tested for final body weights, body weight gain, feed consumption and feed conversion.

Table 5 which shows the response of broiler chicks to boiled and roasted soybean diets for the first broiler experiment indicated that all the birds fed the boilsoy diets had a higher mean body weight gain ($p < 0.05$) than all the birds fed the roastsoy diets. There was no significant difference between the response of birds fed the SBM (control) diets and either all those birds fed the boilsoy or the roastsoy diets for all the parameters studied. Tables 8 and 9 present the results for the first broiler experiment on the effect of levels of boiled and roasted soybean meals, respectively, in broiler diets. These tables also indicate no adverse effects on the birds by feeding any of the three levels (10, 20 and 30 percent) of either the boilsoy or the roastsoy in broiler diets for all the parameters examined when compared with the results of those birds fed the SBM (control) diet.

In the second broiler experiment, however, Table 11 which shows the response of broiler chicks to boiled and roasted soybean meal diets for both sexes together indicated no significant difference between all the birds fed the boilsoy diets and all those birds that consumed the roastsoy diets for all the parameters studied except for feed conversion. This table indicated a better feed conversion for all the birds fed the roastsoy diets compared with all those that were fed the boilsoy diets. Table 11 also indicated a lower performance by the birds fed the boilsoy than those fed the SBM (control) diet for final body weight and body weight gain both at the 0.05 level of probability. The birds fed the roastsoy diets, on the other hand, performed satisfactorily when compared with those that consumed the SBM (control) diet for all the parameters studied.

Tables 14 and 15 show the effect of levels of boiled or roasted soybean meals, respectively, in broiler diets for the second broiler experiment. Table 14 indicated that the birds fed the 10% boilsoy diet had no significant difference in their response for all the parameters studied when compared with those birds fed the SBM (control) diet. The 20% or 30% boilsoy diets resulted in birds that performed less than those fed the SBM (control) diet for final body weight and body weight gain. With the 10, 20 and 30 percent roastsoy diets, however, the birds performed satisfactorily at all levels and for all the parameters studied when compared with the birds that consumed the SBM (control) diet except the significantly lower final weight ($p < 0.05$) obtained from the birds that consumed the 30% roastsoy diet (see Table 15).

In general, for all the parameters studied in both broiler experiments, the performances of the birds fed the roasted soybean were quite satisfactory when compared with those obtained from the birds fed the SBM (control) diets. These results agreed with the reports of many previous workers that heat treatment improves the nutritional values of soybeans (Obsorne and Mendel, 1917; Hayward et al., 1936; Hayward and Hafner, 1941; Rogler and Carrick, 1961; Scott et al., 1971).

The results for the birds fed the boilsoy diets, however, were not consistent for both broiler studies. The birds fed the boilsoy diets performed as well as those fed the SBM (control) diet for all the parameters studied in the first broiler feeding experiment. This observation also agreed with the reports of many previous workers in this field that moist heat treatment improves the nutritional values of soybeans (Fritz et al., 1947; Hayward, 1951; Renner et al., 1953; Rogler and Carrick, 1961). In the second broiler feeding experiment however, the birds fed the boilsoy diets did not perform as well as those fed the control diet for final body weight and body weight gain (Table 14).

It was noticed in the two broiler feeding experiments that the amount of feed consumed by the birds fed the boilsoy and roastsoy diets were lower than the amount consumed by the birds fed the SBM (control) diet. This reduced feed consumption for both the boilsoy and roastsoy diets was not significant during the first broiler feeding experiment but in the second experiment, the birds fed either the 20% or the 30% boilsoy diets, or either the 10%, 20% or the 30% roastsoy diet consumed significantly less feed than the birds fed the control diet. These reduced feed consumptions were also reflected through the significantly lower final body weights and body weight gain obtained by the birds fed the 20% and the 30% boilsoy diets when compared with those fed the SBM (control) diet.

There seems to be no definite explanation for the lower final weights and weight gain obtained in the second broiler experiment for the birds fed the 20 and 30 percent boilsoy diets. One probable cause for this poor growth performance by the birds fed the boilsoy diets may relate to the effect of soaking soybeans in water during cooking. According to Hand (1966), soaking of soybeans can bring about changes in composition in two possible ways. Firstly by leaching of solutes and secondly by *in situ* biochemical changes. Since the leaching effect appears to be accentuated by soaking at elevated temperatures, one could expect this factor to be responsible for part of the lower growth response of the birds fed the boilsoy diets in the second broiler feeding trial. The amount of fat added during roasting after boiling for the roastsoy ingredient might have restored some of the energy lost through the leached carbohydrates during the boiling stage of the roastsoy preparation. This might have accounted for the better growth results obtained from the broilers fed the roastsoy diets.

Some of the factors that could possibly cause the discrepancy between the first and the second broiler feeding experiments include (a) difference in the time the two experiments were conducted. There was a five month gap between the first and the second experiment. (b) The composition of the rations for the second experiment was slightly different from those of the first trial. For example, meat and bone meal was added at the 5% level in the first experiment but at 3% level in the second experiment although the calculated analyses of the rations for both experiments were kept quite similar. (c) The collection time for the roasted soybean wastes and the storage conditions within the oil roast plant, both of which were beyond the control of the researcher, could be adequate for the development of mold and oxidative rancidity in the total fat content of the oil roast soybean wastes (roastsoy). This factor, again, might have decreased the energy value of the roastsoy diets. It could also have decreased the palatability of the roastsoy diets to some degree especially for the second broiler feeding experiment. In the light of the uncertainty just mentioned, it is suggested that further work in this area should investigate whether the use of antioxidant and fungistats would help to eliminate the slight problem of lower final body weight observed with birds fed the 30% roastsoy broiler diet in the second feeding experiment. (d) The fourth factor is the difference in the duration of the two experiments. The first broiler feeding experiment lasted 7 1/2 weeks, while the second feeding experiment lasted 5 1/2 weeks. There is a possibility for the development of a physiological adaptation by the broiler chicks to any of the diets with age. The chicks that were fed a certain diet for a longer period of time are more likely to be able to digest and absorb some particular nutrients more efficiently from the diet (Saxena et al., 1963; Alumot and Nitsan, 1961; Nesheim et al., 1962). The two weeks difference in the age at which the two experiments were terminated could make a difference in the response of the birds to the diets, especially if the birds become more adapted to the diets with time and/or age.

Lack of significant difference in the response between the broilers fed 0.2% DL-methionine and those fed 0.4% DL-methionine for all the parameters tested as indicated in Table 16 suggests that the sulfur amino acid requirements of the broiler chicks were met even at the lower level of methionine supplementation for the boilsoy and the roastsoy diets. This may also mean that the trypsin inhibitor contents of the soybeans were reduced low enough to prevent pancreatic hypertrophy and excessive endogenous nitrogen loss from hypersecretion of pancreatic enzymes (Lyman and

Lepkovsky, 1957; Booth et al., 1972).

Judging from the results of the two broiler feeding experiments, it appears that up to 25% roastsoy could be incorporated into broiler diets without adverse effects on the growth of broilers provided the diets contain other sources of protein rich in methionine. As for the boilsoy, although the results of the first broiler experiment indicated that up to 30% of this ingredient could safely be incorporated into broiler diets without adverse effects on growth, the results of the second broiler experiment however, did not agree with this. The results of the second broiler experiment indicated that not more than 10% boilsoy could be incorporated into broiler rations without adverse effects on growth. Based on these results, it appears there is a possibility that boilsoy may be incorporated into broiler rations up to 30% level provided the rations contain other sources of protein high in methionine. It is only reasonable at this moment to suggest limiting boilsoy to only 10% of broiler rations. Further work would be required to determine if levels higher than 10% boilsoy in broiler diets might have adverse effects.

Subjective Evaluation of Broiler Meat From Experiment II by Consumer Taste Panel

Treatment Effects

For this study, the term treatment again refers to the three types of soybean meals (SBM-control, boilsoy and roastsoy). The ANOVA on broiler meat quality scores for color, odor, flavor, juiciness, tenderness, overall acceptability and overall ranking are presented in Appendices Tables C-1 to C-7, respectively. A study of the tables shows significant differences in the meat flavor ($p < 0.05$) tenderness ($p < 0.01$) and overall ranking for quality ($p < 0.01$) between the meat from the three groups of birds fed either SBM (control), boilsoy or roastsoy diets. There were no significant differences between those three groups of broiler meat for color, odor, juiciness and overall acceptability.

Table 18 shows the effect of boiled and roasted soybean meal diets on broiler meat quality. The mean values shown are for both sexes. Although the ANOVA indicated a significant difference in the flavor of the meat between the three groups of broilers fed each of the three soybean diets at the 0.05 level of probability, this difference did not show in the comparison of the flavor treatment means for both sexes together. With the sexes separated however, Table 19 which contains the results for the males shows that the meat of the male broilers from the group of birds fed the roastsoy diet scored significantly higher for flavor ($p < 0.01$) than the meat from the male birds fed the SBM (control) diet. There was no significant difference in the broiler meat scores for flavor between those birds fed the roastsoy and the boilsoy diets.

Table 18. Effects of Boiled and Roasted Soybean Meal Diets on Broiler Meat Quality (Results for Both Sexes Combined)

	Juiciness	Tenderness	Overall Acceptability	Overall Ranking	Odor	Color	Flavor
SBM (control) Diet (Means)	3.36^{a}	3.96^{A}	3.84^{a}	2.80^{B}	4.04^{a}	3.96^{a}	3.80^{a}
$\pm$SE	(0.05)	(0.21)	(0.24)	(0.34)	(0.25)	(0.04)	(0.19)
Boilsoy Diet (Means)	3.49^{a}	3.36^{B}	3.85^{a}	2.75^{B}	4.13^{a}	4.11^{a}	3.91^{a}
$\pm$SE	(0.30)	(0.41)	(0.29)	(0.65)	(0.31)	(0.25)	(0.23)
Roastsoy Diet (Means)	3.53^{a}	4.14^{A}	3.99^{a}	3.48^{A}	4.04^{a}	4.20^{a}	4.03^{a}
$\pm$SE	(0.56)	(0.28)	(0.24)	(0.58)	(0.20	(0.19)	(0.13)

Means having common capital or small letter superscripts are not significantly different while means not having common letter superscripts are significantly different at the .01 and .05 levels of probability, respectively.

Tables 19 and 20 show the effects of boiled and roasted soybean meal diets on broiler meat quality for the males and for the females, respectively. These tables together with Table 18 indicated that the type of soybean meal had a significant effect on the tenderness of the broiler meat. In all cases but one, the meat from the birds fed the roastsoy diet was significantly more tender than the meat from the birds fed the boilsoy diet but not significantly more tender than the meat from the birds fed the SBM (control) diet. Table 20 shows that the meat from the females fed the roastsoy diet was more tender than that from the females fed the SBM (control) diet at the 0.01 level of probability.

The meat from the broilers fed the roastsoy diets received an overall ranking for quality which was significantly higher ($P < 0.01$), than the meat from those birds fed either the boilsoy or the SBM (control) diets when the results of both sexes were analyzed together (Table 18). Also the same table shows no significant differences in the scores for overall ranking between the meat from the birds fed the SBM (control) diet and those fed the boilsoy diet. With the results for the sexes analyzed separately, Table 19 shows that the meat of the male birds fed the SBM (control) diet received an almost equal overall ranking (3.76) with the meat of the male birds fed the roastsoy diet which had a score of 3.67. The meat of the male birds fed either the SBM (control) diet or those fed the roastsoy diet

Table 19. Effects of Boiled and Roasted Soybean Meal Diets on Broiler Meat Quality (Results for Males)

	Juiciness	Tenderness	Overall Acceptability	Overall Ranking	Odor	Color	Flavor
SBM (control) Diet (Means)	3.48^{a}	3.90^{A}	3.83^{a}	3.76^{A}	4.13^{a}	4.00^{a}	3.75^{B}
$\pm$SE	(0.33)	(0.08)	(0.34)	(0.49)	(0.30)	(0.35)	(0.19)
Boilsoy Diet (Means)	3.35^{a}	3.33^{B}	3.88^{a}	2.63^{B}	4.23^{a}	4.20^{a}	4.00^{AB}
$\pm$SE	(0.21)	(0.49)	(0.22)	(0.74)	(0.38)	(0.22)	(0.27)
Roastsoy Diet (Means)	3.60^{a}	4.15^{A}	4.10^{a}	3.67^{A}	4.10^{a}	4.23^{a}	4.10^{A}
$\pm$SE	(0.42)	(0.33)	(0.18)	(0.65)	(0.25)	(0.19)	(0.08)

Means having common capital or small letter superscripts are not significantly different while means not having common letter superscripts are significantly different at the .01 and .05 levels of probability, respectively.

Table 20. Effects of Boiled and Roasted Soybean Meal Diets on Broiler Meat Quality (Results for Females)

	Juiciness	Tenderness	Overall Acceptability	Overall Ranking	Odor	Color	Flavor
SBM (control) Diet (Means)	3.25^{a}	3.03^{C}	3.85^{a}	2.84^{a}	3.95^{a}	3.93^{a}	3.85^{a}
$\pm$SE	(0.57)	(0.29)	(0.13)	(0.17)	(0.19)	(0.50)	(0.13)
Boilsoy Diet (Means)	3.62^{a}	3.40^{B}	3.83^{a}	2.87^{a}	4.03^{a}	4.03^{a}	3.83^{a}
$\pm$SE	(0.33)	(0.38)	(0.38)	(0.63)	(0.22)	(0.28)	(0.17)
Roastsoy Diet (Means)	3.45^{a}	4.13^{A}	3.88^{a}	3.30^{a}	3.98^{a}	4.18^{a}	3.95^{a}
$\pm$SE	(0.73)	(0.26)	(0.26)	(0.54)	(0.15)	(0.22)	(0.13)

Means having common capital or small letter superscripts are not significantly different while means not having common letter superscripts are significantly different at the .01 and .05 levels of probability, respectively.

received an overall ranking for quality significantly higher ($p < 0.01$) than the meat from the male birds fed the boilsoy diet. It was observed from Table 18 that the meat from the birds fed the roastsoy diet received the highest scores for juiciness, tenderness, overall acceptability, overall ranking, color and flavor. This would possibly suggest an improvement in the meat quality characteristics of the broilers by the roastsoy diet.

Influence of Sex of Broilers on Consumer Taste Panel Meat Scores

The ANOVA tables in Appendices C-1 to C-7 indicated that sex of broilers had no significant effect on meat color, odor, flavor, juiciness, tenderness, overall acceptability and overall ranking. Table 21 shows the effects of boiled and roasted soybean meal diets on broiler meat quality. This table gives the comparisons of means for both sexes together and separated, for each type of soybean meal diet and for each of the various meat quality parameters studied. This table also indicates no significant influence of sex on juiciness, odor, color and flavor of broiler meat. There were, however, significant differences between the sexes for tenderness and overall ranking among the birds fed the SBM (control) diet, and for overall acceptability and overall ranking among the birds fed the roastsoy diet.

Table 21 also indicated that the male broilers fed the SBM (control) diet were more tender than the females

Table 21. Effect of Boiled and Roasted Soybean Meal Diets on Broiler Meat Quality (Males, Females and Both Sexes Combined)

Treatment	Juiciness		Tenderness		Overall Acceptability		Overall Ranking		Odor		Color		Flavor	
	Means	±SE	Means	±SE	Means	±SE	Means	±SE	Means	±SE	Means	±SE	Means	±SE
SBM (control) Diet														
Males & Females	3.36^{a}	0.45	3.96^{A}	0.21	3.84^{a}	0.24	2.80^{a}	0.34	4.04^{a}	0.25	3.96^{a}	0.40	3.80^{a}	0.16
Males	3.48^{a}	0.33	3.90^{A}	0.08	3.83^{a}	0.34	3.76^{b}	0.49	4.13^{a}	0.30	4.00^{a}	0.35	3.75^{a}	0.19
Females	3.25^{a}	0.57	3.03^{B}	0.29	3.85^{a}	0.13	2.84^{a}	0.17	3.95^{a}	0.19	3.93^{a}	0.50	3.85^{a}	0.13
Boilsoy Diet														
Males & Females	3.49^{a}	0.30	3.36^{a}	0.41	3.85^{a}	0.29	2.75^{a}	0.65	4.13^{a}	0.31	4.11^{a}	0.25	3.91^{a}	0.23
Males	3.35^{a}	0.21	3.33^{a}	0.49	3.88^{a}	0.22	2.63^{a}	0.74	4.23^{a}	0.38	4.20^{a}	0.22	4.00^{a}	0.27
Females	3.62^{a}	0.33	3.40^{a}	0.38	3.83^{a}	0.38	2.87^{a}	0.63	4.03^{a}	0.22	4.03^{a}	0.28	3.83^{a}	0.17
Roastsoy Diet														
Males & Females	3.53	0.56	4.14^{a}	0.28	3.99^{ab}	0.24	3.48^{ab}	0.58	4.04^{a}	0.20	4.20^{a}	0.19	4.03^{a}	0.13
Males	3.60^{a}	0.42	4.15^{a}	0.33	4.10^{a}	0.18	3.67^{a}	0.65	4.10^{a}	0.25	4.23^{a}	0.19	4.10^{a}	0.08
Females	3.45^{a}	0.73	4.13^{a}	0.26	3.88^{b}	0.26	3.30^{c}	0.54	3.98^{a}	0.15	4.18^{a}	0.22	3.95^{a}	0.13

Within each type of soybean meal diet, means having common capital or small letter superscripts are not significantly different while means not having common letter superscripts are significantly different at the .01 and .05 levels of probability, respectively.

fed the same diet ($p < 0.01$). It should be realized, however, that these broilers were only 5 1/2 weeks old and were not finished. It is most likely therefore, that any difference observed in the meat tenderness at this stage of growth could be due to mere chance. The male broilers from the group fed the roastsoy diet received higher scores for overall acceptability and for overall ranking ($p < 0.05$) than the females that received the same diet.

Effect of Meat Type (Light versus Dark Meat) on Taste Panel Scores

The ANOVA tables (Appendices Tables C-1 to C-7) indicate that meat type had no significant influence on the broiler meat scores for odor, flavor, overall acceptability and overall ranking but had highly significant influences ($p < 0.01$) on the broiler meat scores for color, juiciness and tenderness.

Tables 22 and 23 show the influence of boiled and roasted soybean meal diets on broiler meat quality for light and dark meat, respectively. These tables show the comparisons of means for the three groups of birds fed each of the three types of soybean meal (SBM, boilsoy and roastsoy) diets for the various parameters studied. Table 22 for light meat indicated no significant differences between the birds fed either the SBM (control), the boilsoy or the roastsoy diets for all the parameters studied except for flavor. The meat from the birds fed the boilsoy diet was

Table 22. Effects of Boiled and Roasted Soybean Meal Diets on Broiler Meat Quality (Results for Light Meat)

	Juiciness	Tenderness	Overall Acceptability	Overall Ranking	Odor	Color	Flavor
SBM (control) Diet (Means)	3.00^{a}	4.08^{a}	3.7^{a}	2.60^{a}	4.05^{a}	4.25^{a}	3.75^{b}
$\pm$SE	(0.29)	(0.15)	(0.22)	(0.29)	(0.17)	(0.26)	(0.17)
Boilsoy Diet (Means)	3.43^{a}	3.90^{a}	4.03^{a}	3.30^{a}	4.15^{a}	4.2^{a}	4.05^{a}
$\pm$SE	(0.39)	(0.20)	(0.28)	(0.29)	(0.34)	(0.22)	(0.24)
Roastsoy Diet (Means)	3.13^{a}	4.28^{a}	3.85^{a}	3.10^{a}	3.98^{a}	4.35^{a}	3.95^{ab}
$\pm$SE	(0.52)	(0.33)	(0.24)	(0.57)	(0.29)	(0.13)	(0.13)

Means with the same letter superscript do not differ significantly at 0.05 level of probability.

Table 23. Effects of Boiled and Roasted Soybean Meal Diets on Broiler Meat Quality (Results for Dark Meat)

	Juiciness	Tenderness	Overall Acceptability	Overall Ranking	Odor	Color	Flavor
SBM (control) Diet (Means)	3.73^{a}	3.85^{Ab}	3.98^{ab}	2.99^{ABb}	4.03^{a}	3.68^{a}	3.88^{ab}
$\pm SE$	(0.17)	(0.21)	(0.19)	(0.30)	(0.34)	(0.29)	(0.13)
Boilsoy Diet (Means)	3.55^{a}	3.00^{Bc}	3.68^{b}	2.20^{Bc}	4.10^{a}	4.03^{a}	3.78^{b}
$\pm SE$	(0.19)	(0.20)	(0.19)	(0.29)	(0.32)	(0.28)	(0.13)
Roastsoy Diet (Means)	3.93^{a}	4.28^{Aa}	4.13^{a}	3.87^{Aa}	4.10^{a}	4.05^{a}	4.10^{a}
$\pm SE$	(0.17)	(0.14)	(0.17)	(0.28)	(0.00)	(0.10)	(0.08)

Means having common capital or small letter superscripts are not significantly different while means not having common letter superscripts are significantly different at the .01 and .05 levels of probability, respectively.

scored significantly higher for flavor ($p < 0.05$) than the meat from the birds fed the SBM (control) diet. There were no significant differences in the light meat scores for flavor between the birds fed the boilsoy diet and those from the birds fed the roastsoy diet or between the birds fed the roastsoy and those birds fed the SBM (control) diet. The three groups of birds fed either the SBM (control), the boilsoy or the roastsoy diets similarly indicated no significant differences between their dark meat scores for juiciness, odor, and color but there were significant differences in their dark meat score for tenderness, overall acceptability, overall ranking and flavor (Table 23).

The dark meat from the birds fed the roastsoy diet was more tender than the dark meat from the birds fed either the SBM (control) diet ($p < 0.05$) or that from the birds fed the boilsoy diet ($p < 0.01$). The dark meat from the birds fed roastsoy diet also had better flavor ($p < 0.05$) than that from the birds fed the boilsoy diet but not significantly better than the dark meat from the birds fed the control diet.

The dark meat from the birds fed the roastsoy diet received the highest score for overall acceptability. The score was not significantly higher than for the dark meat from the birds fed the SBM (control) diet, but was significantly higher than the score for the dark meat from the birds fed the boilsoy diet ($p < 0.05$). There was no significant difference for the dark meat score for overall acceptability between the birds fed the SBM (control) diet and those fed the boilsoy diet.

Table 24 shows the comparison of light and dark broiler meat scores for each type of soybean meal diet and for the various parameters studied. The light meat from the birds fed the SBM (control) diet was less juicy ($p < 0.01$), but had a more acceptable color ($p < 0.01$), than the dark meat from the same diet. The light meat from the birds fed the boilsoy diet was less juicy ($p < 0.05$), but more tender ($p < 0.01$), more acceptable ($p < 0.05$), higher in overall ranking ($p < 0.01$) and had better flavor ($p < 0.05$), than the dark meat from the same diet. The light meat from the birds fed the roastsoy diet was less juicy ($p < 0.01$), and had a significantly lower overall ranking than the dark meat from the same diet ($p < 0.01$).

From this taste panel evaluation the broiler meat from the birds fed the roastsoy diet was the most preferred by the panelists since the meat received the highest scores for nearly all the meat quality parameters except for odor. The analysis of variance indicated that the diets had significant influence on flavor but when the means for flavor for each diet for both sexes were compared as shown in Table 18, this difference in flavor could not be detected by the Bonferroni t-statistics. When the results for the males were separated before making the comparisons, as presented in Table 19, it

Table 24. Effects of Boiled and Roasted Soybean Meal Diets on Broiler Meat Type Quality (Comparisons of Light and Dark Meat for Each Diet)

	Juiciness		Tenderness		Overall Acceptability		Overall Ranking		Odor		Color		Flavor	
	Mean	±SE	Mean	±SE	Mean	±SE	Mean	±SE	Mean	±SE	Mean	±SE	Mean	±SE
SBM (control) Diet														
Light meat	3.00^{B}	.29	4.08^{a}	.15	3.70^{a}	.22	2.60^{a}	.29	4.05^{a}	.17	4.25^{A}	.26	3.73^{a}	.17
Dark meat	3.73^{A}	.17	3.85^{a}	.21	3.98^{a}	.19	2.99^{a}	.30	4.03^{a}	.34	3.68^{B}	.29	3.88^{a}	.13
Boilsoy Diet														
Light meat	3.43^{b}	.39	3.90^{A}	.24	4.03^{a}	.28	3.30^{A}	.29	4.15^{a}	.34	4.20^{a}	.22	4.05^{a}	.24
Dark meat	3.55^{a}	.19	3.00^{B}	.20	3.68^{b}	.19	2.20^{B}	.29	4.10^{a}	.32	4.03^{a}	.28	3.78^{b}	.13
Roastsoy Diet														
Light meat	3.13^{B}	.52	4.28^{a}	.33	3.85^{a}	.24	3.10^{B}	.57	3.98^{a}	.29	4.35^{a}	.13	3.95^{a}	.13
Dark meat	3.93^{A}	.17	4.00^{a}	.14	4.13^{a}	.17	3.87^{A}	.28	4.10^{a}	.00	4.05^{a}	.10	4.10^{a}	.08

Means having common capital or small letter superscripts are not significantly different while means not having common letter superscripts are significantly different at the .01 and .05 levels of probability, respectively. (Comparisons are made within each diet separately.)

was found that the meat from the birds fed the roastsoy diet received significantly higher score for flavor ($p < 0.01$) than the meat from the birds fed the SBM (control) diet but not significantly higher than the score for flavor for the meat from the birds fed the boilsoy diet.

The significant influence of the roastsoy diet on the meat flavor was expected because the browning reaction of soybeans during oil roasting usually involves some degree of Maillard reaction, caramelization of the sugars and flavor improvement. The flavor developed from the roasting process might have improved the flavor of the meat of the birds fed the roastsoy diet. This in turn could have led to the highest score for overall ranking received by the meat from the birds fed the roastsoy diet.

Experiment III - Layer Feeding Experiment

Treatment Effects

Treatment in this experiment refers to the three types of soybean meal diets--SBM (control), boilsoy and the roastsoy diets, while the soybean meal levels were 7.5, 15 and 22.5 percent of the ration for the boilsoy and the roastsoy diets. The only level for the SBM (control) diet was the 19.6% of SBM-48 which supplied the maximum amount of SBM required to make up the balance of the vegetable protein of the control ration.

The ANOVA of the layer data for total egg number, hen-day egg production, hen-housed egg production, feed consumption, feed efficiency (kg/dozen eggs), pancreas weights, body weight gain and mortality are presented in the Appendices Tables D-1 to D-8), respectively. The ANOVA tables show that treatment (type of soybean meal) had no significant effect on the birds for all the parameters studied.

Table 25 shows the effects of boiled and roasted soybean meal diets on the performance of laying hens. The mean values of the boilsoy and the roastsoy diets for all the parameters shown represent the mean values for all the birds fed each of the three levels of either the boilsoy or the roastsoy diets. The standard error of means are in brackets under each mean value. This table also indicated no significant differences between the birds fed either the boilsoy, the roastsoy or the SBM (control) diets for all the parameters studied.

Effect of Soybean Meal Levels

The tables of ANOVA (Appendices D-1 to D-8) revealed no significant effect of the soybean meal levels on the layers' response to all the parameters studied except for pancreas weights. Table 26 shows the effects of levels of boiled soybean meal diets on the performance of laying hens. The standard errors for each mean are also shown in brackets under each mean. This table also revealed no significant

Table 25. Effects of Boiled and Roasted Soybean Meal Diets on the Performance of Laying Hens

	Egg weight (gms)	Egg No. per bird	Hen-day prodn (%)	Hen-Housed prodn (%)	Feed Consumption (gms/bird/day	Feed Efficiency (kg/doz. eggs)	Weight gain (gms/bird)	Pancreas weight (gms)	Mortality	
									%	Actual Dead
SBM (control) Diet (Means)	57.21[a]	96.26[a]	68.00[a]	67.28[a]	110.40[a]	1.97[a]	174.31[a]	3.26[a]	6.25[a]	2/32
±SE	(4.7)	(29.7)	(8.0)	(8.4)	(10.9)	(.29)	(224.2)	(0.45)	(0.95)	
Boilsoy Diets (Means)	58.43[a]	90.53[a]	64.58[a]	63.13[a]	110.87[a]	2.11[a]	149.25[a]	3.05[a]	5.21[a]	5/96
±SE	(5.2)	(33.5)	(10.0)	(10.2)	(11.4)	(.39)	(195.5)	(0.53)	(0.29)	
Roastsoy Diets (Means)	56.91[a]	93.74[a]	66.71[a]	65.65[a]	108.35[a]	1.99[a]	160.71[a]	3.02[a]	3.13[a]	3/96
±SE	(5.4)	(32.2)	(9.3)	(9.8)	(11.4)	(.37)	(195.5)	(0.50)	(0.23)	

Means with the same letter superscript do not differ significantly at the 0.01 level of probability.

Table 26. Effects of Levels of Boiled Soybean Meal Diets on the Performance of Laying Hens

	Egg weight (gms)	Egg No. per bird	Hen-day prodn (%)	Hen-Housed prodn (%)	Feed Consumption (gms/bird/day	Feed Efficiency (kg/doz. eggs)	Weight gain (gms/bird)	Pancreas weight (gms)	Mortality %	Mortality Actual Dead
SBM (control) Diet (Means)	57.2[a]	93.3[Aa]	68.0[a]	67.3[a]	110.40[a]	1.97[a]	174.31[a]	3.25[a]	6.25[a]	2/32
±SE	(4.7)	(29.7)	(8.0)	(8.4)	(10.9)	(0.29)	(224.2)	(0.45)	(2.78)	
7.5% Boilsoy Diet (Means)	58.1[a]	92.2[ABa]	65.7[a]	63.8[a]	113.05[a]	2.11[a]	194.50[a]	3.15[a]	6.25[a]	2/32
±SE	(5.1)	(33.8)	(10.1)	(10.9)	(12.5)	(0.44)	(170.6)	(0.61)	(1.72)	
15% Boilsoy Diet (Means)	58.9[a]	93.2[Aa]	66.6[a]	64.2[a]	111.72[a]	2.05[a]	119.66[a]	3.22[a]	9.38[a]	3/32
±SE	(5.1)	(32.4)	(10.1)	(10.4)	(11.9)	(0.34)	(208.9)	(0.50)	(1.72)	
22.5% Boilsoy Diet (Means)	58.3[a]	86.3[Bb]	61.4[a]	61.4[a]	107.8[a]	2.15[a]	133.59[a]	2.79[a]	0.00[a]	0/32
±SE	(5.5)	(34.0)	(9.5)	(9.5)	(9.5)	(0.40)	(207.0)	(0.40)	(0.0)	

Means having common capital or small letter superscripts are not significantly different while means not having common letter superscripts are significantly different at the .01 and .05 levels of probability, respectively.

differences between the birds fed the SBM (control) diet and any of the groups of birds fed each of the three levels of boilsoy (7.5, 15 and 22.5 percent) diets for all the layer parameters studied except for egg numbers. The birds fed the 22.5% boilsoy diet produced a lower number of eggs per bird than the birds fed either the 7.5% boilsoy diet ($p < 0.05$), 15% boilsoy diet ($p < 0.01$) or the SBM (control) diet ($p < 0.01$). The standard error of mean for egg number shows that the birds fed the 22.5% boilsoy had the largest variation when compared with the results for the groups of birds fed any other diet. The ANOVA table in Appendix D-1 for egg numbers also indicated a highly significant bird variation at 0.01 level of probability.

The lower egg number obtained for the group of birds fed the 22.5% boilsoy diet may therefore not be related to the nature of the diet fed. When the egg numbers were transformed into percent hen-day or percent hen-housed egg production, there were no significant differences observed between the birds fed the SBM (control) diet and those fed any of the three levels of boilsoy diets.

Table 27 shows the effects of levels of roasted soybean meal diets on the performance of laying hens. This table again reveals no significant difference between the birds fed the SBM (control) diet and any of the three groups of birds fed each of the levels of roastsoy (7.5, 15 and 22.5 percent) diets for all the parameters studied except

Table 27. Effects of Levels of Roasted Soybean Meal Diets on the Performance of Laying Hens

	Egg weight (gms/ egg)	Egg No. per bird	Hen-day prodn (%)	Hen-Housed prodn (%)	Feed Consumption (gms/bird/ day	Feed Efficiency (kg/doz. eggs)	Weight gain (gms/ bird)	Pancreas weight (gms)	Mortality %	Mortality Actual Dead
SBM (control) Diet (Means)	57.2[a]	96.3[A]	68.0[a]	67.3[a]	110.40[a]	1.97[a]	174.31[a]	3.26[a]	6.25[a]	2/32
±SE	(4.7)	(29.7)	(8.0)	(8.4)	(10.9)	(0.29)	(224.2)	(0.45)	(2.78)	
7.5% Roastsoy Diet (Means)	56.8[a]	86.9[B]	61.9[a]	61.2[a]	106.88[a]	2.14[a]	167.74[a]	3.31[a]	3.13[a]	1/32
±SE	(6.8)	(35.7)	(11.2)	(12.4)	(10.9)	(0.51)	(177.8)	(0.51)	(1.41)	
15% Roastsoy Diet (Means)	56.9[a]	98.6[A]	70.3[a]	67.7[a]	109.78[a]	1.89[a]	143.00[a]	2.93[a]	3.13[a]	1/32
±SE	(4.4)	(28.5)	(7.9)	(8.4)	(11.0)	(0.26)	(210.5)	(0.41)	(1.41)	
22.5% Roastsoy Diet (Means)	57.0[a]	95.9[A]	68.0[a]	68.0[a]	108.38[a]	1.92[a]	171.38[a]	2.82[a]	0.00[a]	0/32
±SE	(5.0)	(31.0)	(6.4)	(6.4)	(12.6)	(0.24)	(198.0)	(0.46)	(0.0)	

Means having common capital or small letter superscripts are not significantly different while means not having common letter superscripts are significantly different at the .01 and .05 levels of probability, respectively.

for egg number per bird. The birds fed the 7.5% roastsoy diet laid fewer eggs than the birds fed either the 15%, or the 22.5% roastsoy diets, or the SBM (control) diet at 0.01 level of probability. The reason for the lower egg number from the birds fed the 7.5% roastsoy diet is not clear. It could also be observed from Table 27, however, that there was a high degree of variation as indicated by the large values for the standard errors of means. The standard error of mean was highest for the birds fed the 7.5% roastsoy (86.9 $\pm$ 35.7). The table of Appendix D-1 on the ANOVA for total number of eggs also shows that there was a high degree of bird variation at 0.01 level of probability. It is therefore possible that the lower egg number obtained from the birds fed 7.5% roastsoy was not due to the diet fed. Lack of significant differences between the pancreas weights of the birds fed any of the diets for this trial also suggests a substantial reduction in the level of trypsin inhibitor content of the boilsoy and roastsoy ingredients by the amount of heat applied during processing (Rackis and McGhee, 1975).

Effect of Periods

As expected, the ANOVA indicated a high significant effect of period at 0.01 level of probability on the birds for all the parameters except for mortality. The rate of mortality was very low for all the diets; 2 out of 32 birds for the birds that received the control diet, 5 out of 96 birds for those birds fed the boilsoy diets and 3 out of 96 birds for the groups of birds fed the roastsoy diets.

Tables 28 and 29 show the percent hen-day and hen-housed egg production and the standard error of means by 28 day periods for each diet fed. The results in these tables suggest that the birds were either already at the peak of the production curve right from the beginning of the experiment or more likely, that the birds were set back in production and could not quite attain the potential peak of production due to the stress from handling and weighing for the experiment after the production had started.

The birds fed the diets that contained the roastsoy ingredient performed just as well in this layer feeding experiment as broilers fed in the two broiler feeding experiments. This satisfactory result for the birds fed the roastsoy diets agreed with many previous reports that heat treatment improved the nutritional values of soybeans (Hayward and Hafner, 1941; Clandinin et al., 1947; Fritz et al., 1947; Renner and Hill, 1960; Rogler and Carrick, 1961; Scott et al., 1971; Rackis et al., 1975; Liener, 1977). The results here suggest that the roastsoy could be incorporated into laying rations up to 22.5% without adverse effects on the performance of the laying hens provided the rations contain other sources of critical amino acids such as methionine. As for the birds fed the diets that contained the

Table 28. Percent Hen-Day Egg Production and Standard Error of Means by 28 Day Periods

Periods	Rations	SBM Control	7.5% Boilsoy	15% Boilsoy	22.5% Boilsoy	7.5% Roastsoy	15% Roastsoy	22.5% Roastsoy
1	Means	77.45	73.45	76.25	69.10	72.00	76.68	74.55
	±SE	5.5	7.0	4.8	8.8	5.6	6.0	2.5
2	Means	65.63	66.28	67.73	62.50	58.15	67.85	63.05
	±SE	5.9	11.6	7.7	11.8	7.4	7.4	8.4
3	Means	63.50	61.08	58.90	55.15	55.88	61.28	65.85
	±SE	10.1	12.4	10.3	12.2	16.1	9.0	6.4
4	Means	64.65	59.25	59.95	61.63	59.60	68.10	70.73
	±SE	8.2	12.7	8.9	7.4	14.9	6.5	4.8
5	Means	65.18	59.03	57.93	58.70	60.40	64.80	64.85
	±SE	5.7	7.1	9.6	3.2	14.0	7.3	2.8

Table 29. Percent Hen-Housed Egg Production and Standard Errors of Means by 28 Day Periods

Periods	Rations	SBM Control	7.5% Boilsoy	15% Boilsoy	22.5% Boilsoy	7.5% Roastsoy	15% Roastsoy	22.5% Roastsoy
1	Means	77.45	73.45	76.25	69.10	72.00	76.67	74.55
	±SE	5.5	7.0	4.8	8.8	5.6	6.0	2.5
2	Means	65.63	67.65	69.25	62.50	58.93	67.85	63.05
	±SE	5.9	11.5	7.8	11.8	6.3	7.4	8.4
3	Means	63.50	62.88	61.38	55.15	57.08	64.53	65.85
	±SE	10.1	10.8	14.1	12.2	13.8	9.8	6.4
4	Means	66.05	61.23	63.93	61.63	60.98	72.80	70.73
	±SE	7.1	10.9	8.1	7.4	12.3	6.9	4.8
5	Means	67.35	63.28	62.25	58.70	60.40	69.40	65.85
	±SE	5.3	9.3	9.5	3.1	14.0	6.4	2.8

boilsoy, there was no adverse effects on the performance of laying hens up to 22.5% boilsoy level for all the parameters studied except for egg numbers per bird. There were, however, strong evidences from the high standard error of mean for egg numbers (Table 26) and from the highly significant bird variation for egg numbers per bird as indicated in the ANOVA (Appendix Table D-1) that the lower egg number for this group of birds fed the 22.5% boilsoy may not be related to the nature of the diet fed.

Despite the evidences advanced to justify the lower egg numbers for the birds fed the boilsoy diets when compared with the birds fed the control diet, it is more realistic to suggest at this stage that the use of boilsoy in layer rations be limited to 15% level until further studies indicate that layer rations may contain higher levels of boilsoy without adverse effects on the laying hens.

Results of the Urease Analysis Tests

Analysis of variance for urease activity measurement by P^H (Table E-1) indicates a highly significant difference in urease activity among the types of soybean meal tested at 0.01 level of probability.

Comparisons of soybean sample means shown in Table 30 revealed that raw soybean meal had significantly higher urease activity ($p < 0.01$) than either the boiled soybean meal (boilsoy), roasted soybean meal (roastsoy) or 48% protein, solvent extracted soybean meal (SBM). Raw soybean

Table 30. Urease Activities of Four Soybean Meal Samples Measured as Increased Change in P^H

	Urease activity (Mean P^H change)	$\pm$SE	No. of Determinations
Raw soybean	2.162^a	0.138	16
Boiled soybean	0.168^b	0.123	16
Roasted soybean	0.065^b	0.113	16
Soybean meal-48% (control)	0.174^b	0.114	16

Means with the same letter superscript do not differ significantly at 0.01 level of probability.

meal had a P^H rise of 2.162 compared with 0.168 rise for boilsoy, 0.065 rise for roastsoy and 0.174 rise for SBM. There were no significant differences in the P^H rise between the boilsoy, roastsoy and SBM samples.

Results of the urease test show a close agreement with that of Hayward (1967) who reported a P^H increase of about 2.0 for raw soybean meal, 0.2 rise for properly cooked soybean meal and 0.05 rise for overcooked soybean meal. The roastsoy in this test with a P^H rise of 0.065 was very close to the value of 0.05 which is the lower limit of the criterion suggested by Hayward before the soybean can be said to be overcooked. The time-temperature-moisture combination applied to the boilsoy, the roastsoy and the SBM can be considered to be adequate according to the criterion of 0.05 to 0.2 P^H rise suggested by Hayward (1967), and according to the criterion of Caskey and Knapp (1944) reported by Bird et al. (1947), that is, a less than "one unit P^H increase" for an adequate heat treatment.

Table 30 shows that the P^H increase of the boilsoy and roastsoy were both less than one unit. This result, according to Caskey and Knapp (1944), indicated that the amount of heat applied to both the boilsoy and the roastsoy used in this study can therefore be said to have improved the nutritional qualities of these products to the standard of the commercially prepared soybean meal used in this study.

SUMMARY OF FINDINGS AND CONCLUSIONS

Three feeding experiments (two with broiler chicks and one with laying hens), one subjective taste panel evaluation of broiler meat eating quality characteristics and urease tests were performed to evaluate the feeding values of boiled soybean (boilsoy) and roasted soybean (roastsoy) for chickens. The following results were obtained.

Broiler Feeding Trials

1. The broiler chicks fed the diets containing up to 30% roastsoy diets compared favorably with the birds fed the control diet for all the parameters examined in the first broiler study. The optimum level of roastsoy in broiler diets for maximum response in the second study was only 25%. It appears therefore, practicable to incorporate up to 25% roastsoy in broiler diets without adverse effects on the growth of broiler chicks provided the rations contain other sources of protein with reasonable methionine content.
2. The broiler chicks fed the boilsoy diets performed satisfactorily compared with the birds fed the control diet for all the parameters studied in the first broiler experiment. The results of the

second broiler feeding experiment, however, were not so encouraging. Although it may be possible to incorporate boilsoy in broiler rations at higher levels, it is more reasonable to suggest that boilsoy should not exceed 10% of broiler rations based on the present results. Further work would be required to determine if levels higher than 10% boilsoy in broiler diets might have adverse effects.

3. The birds fed either the boilsoy or the roastsoy diets consumed significantly less feed than those birds fed the SBM (control) diet. This reduced feed consumption was more pronounced in the second broiler feeding trial. In the second broiler experiment, the birds fed the boilsoy diets and those fed the roastsoy diets consumed significantly less feed ($p < 0.05$ and $p < 0.01$, respectively) than those birds fed the SBM (control) diet. It appears that the higher the level of either the boilsoy or the roastsoy in the diets, the lower the feed consumption.

4. The boilsoy and the roastsoy diets had no hypertrophic effect on the pancreases of the chicks fed these diets in both broiler studies.

5. There was no beneficial effect by supplementing either the boilsoy or the roastsoy diets with DL-Methionine up to 0.4% level.

Consumer Taste Panel Evaluation of Broiler Meat

1. The meat from the birds fed the roastsoy diet had a significantly higher overall ranking for eating quality ($p < 0.01$) than the meat from the birds fed the control diet. There were no significant differences due to dietary treatment between the meat from the roastsoy diet and that from the control diet for all other meat quality characteristics examined.
2. The meat from the birds fed the boilsoy diet was less tender ($p < 0.01$) than the meat from the birds fed the control diet. No significant differences were observed between the meat from the birds fed the boilsoy diet and the meat from the birds fed the control diet for all other meat quality characteristics studied.
3. The birds that were fed the roastsoy diet received the highest scores for most of the meat quality characteristics considered.

Layer Feeding Trial

1. The birds that were fed either 7.5% or 15% boilsoy diets performed (in all parameters studied) as well as those birds that were fed the control diet. The birds fed 22.5% boilsoy diet also performed satisfactorily in all parameters studied, except for their significantly lower egg number ($p < 0.01$), when compared with those birds fed the controled diet.
2. There were no significant differences in any of the parameters studied between the birds fed either 7.5%, 15% or 22.5% roastsoy diets when compared with those birds fed the control diet except for the significantly lower egg number ($p < 0.01$) for the birds fed 7.5% roastsoy diet.
3. Judging from the overall results of the layer feeding trial, it is concluded that up to 22.5% roastsoy may be included in laying rations without any adverse effect on the performance of the birds provided the rations contain adequate sources of methionine. Also, boilsoy may be used up to 15% in laying rations. Further work would be required to determine if levels higher than 15% boilsoy in laying rations might have adverse effects.

Urease Activity Tests

The results of the urease activity tests showed that the condition of time-temperature-moisture combination applied to the boilsoy and roastsoy during the processing improved their nutritional qualities to levels of 48% protein, solvent extracted soybean meal used in this study.

SUGGESTIONS FOR FURTHER STUDIES

Based on the results and observations made during this study on the evaluation of boiled soybeans and boiled/roasted soybeans as feed ingredients for broiler and layer rations, the following areas of further studies are suggested:

1. Studies on the feeding of graded levels of boiled soybeans to both broilers and layers to determine if levels higher than 10% (broiler rations) and 15% (layer rations) established from this study could be fed in poultry rations.
2. Determination of the optimum level of methionine supplementation in boiled soybean broiler diets. The optimum supplementary level of DL-methionine may fall somewhere between the 0.2% and 0.4% levels examined in this study.
3. To determine if lysine supplementation could improve the nutritive value of the boiled/roasted soybeans for both broilers and layers.
4. To determine if the nutritive value of the boiled/roasted soybean ingredient could be improved by the addition of an antioxidant and/or a fungistat. This study could be preceded by first determining if the boiled/roasted soybean by-product really undergoes some degree of oxidative rancidity and/or moldiness at any of the various stages of processing and storage.

All the feeding experiments may involve peanut meal diets as comparisons in those areas where peanut meal serves as the major source of vegetable protein for poultry rations.

5. When further studies indicate that boiled soybeans and boiled/roasted soybeans may be used successfully in broiler or layer rations without adverse effects, there would be a need to establish standards for the nutrient composition of the two ingredients to facilitate trade and to permit uniformity of the ingredients for ration formulations. Such standards should include:

(a) Metabolizable energy content for poultry K.cal/Kg.
(b) Percent minimum fat
(c) Percent minimum crude protein
(d) Percent minimum available lysine
(e) Percent maximum fiber
(f) Percent maximum sodium

6. Following the above, there would be a need to determine the monetary values of the boiled soybean and the boiled/roasted soybean meals so as to arrive at prices that the producers of the by-product might expect. In such areas where oil roast soybean industries do not exist, the determination of monetary value would only be required for the boiled soybean as a poultry feed ingredient. Factors to consider should include costs of the raw products as well as handling and processing costs so that individuals and companies interested may determine the feasibility of establishing trade in the processing and marketing of this product on a commercial scale.

APPENDIX A

Analysis of Variance (ANOVA) Tables for Broiler Feeding Experiment I

Table A-1. ANOVA for Broiler Final Weight

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Statistics
Treatment	2	1190.267	595.134	0.017
Level/Trt	4	113460.703	28365.176	0.809
Replicate	2	50750.571	25375.286	0.698
Error a	12	420744.459	35062.038	
Period	3	65264673.103	21754891.034	598.545*
Trt x Per	6	86726.105	14454.351	0.398
Level/Trt x Per	12	321684.770	26807.064	0.738
Rep x Per	6	91785.120	15297.520	0.421
Trt x Rep x Per	12	234386.874	19530.573	0.537
Sex	1	1275408.940	1275408.940	35.090*
Initial weight	1	0.318	0.318	0.0000087
Error b	106	3852708.677	36346.308	
Total	167	71713519.910	429422.275	

*Significant at .01 level of probability.

Table A-2. ANOVA for Broiler Weight Gain

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Statistics
Treatment	2	4979.703	2489.852	0.699
Level/Trt	4	12664.379	3166.095	0.889
Replicate	2	1724.242	862.121	0.361
Error a	12	42744.265	3562.022	
Period	3	3439535.991	1146511.997	479.938*
Trt x Per	6	4275.340	712.557	0.298
Level/Trt x Per	12	39952.197	3329.350	1.394
Rep x Per	6	3715.447	619.241	0.259
Trt x Rep x Per	12	13615.053	1134.588	0.475
Sex	1	366904.335	366904.335	153.589*
Error b	107	255609.392	2388.873	
Total	167	4185720.344	25064.194	

*Significant at .01 level of probability.

Table A-3. ANOVA for Broiler Feed Consumption

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Statistics
Treatment	2	5941.076	2970.538	0.525
Level/Trt	4	42463.816	10615.954	1.877
Replicate	2	7439.252	3719.626	2.271
Error a	12	67886.794	5657.233	
Period	3	13528827.450	4509609.150	2753.492*
Trt x Per	6	7395.212	1232.535	0.753
Level/Trt x Per	12	40768.845	3397.404	2.074
Rep x Per	6	15063.671	2510.612	1.533
Trt x Rep x Per	12	19889.729	1657.477	1.012
Error b	24	39306.671	1637.778	
Total	83	13774982.520	165963.645	

*Significant at .01 level of probability.

Table A-4. ANOVA for Broiler Feed Conversion

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Statistics
Treatment	2	0.005	0.002	0.2
Level/Trt	4	0.092	0.023	2.3
Replicate	2	0.010	0.005	0.385
Error a	12	0.116	0.01	
Period	3	15.309	5.103	392.538*
Trt x Per	6	0.053	0.009	0.692
Level/Trt x Per	12	0.116	0.010	0.769
Rep x Per	6	0.026	0.004	0.308
Trt x Rep x Per	12	0.103	0.009	0.692
Error b	24	0.305	0.013	
Total	83	16.135	0.194	

*Significant at .01 level of probability.

Table A-5. ANOVA for Broiler Pancreas Weights

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Statistics
Treatment	2	0.192	0.096	0.681
Level/Trt	2	0.672	0.336	2.383
Replicate	2	0.965	0.483	5.963*
Error a	12	1.697	0.141	
Period	1	41.664	41.664	514.370**
Trt x Per	2	0.331	0.166	2.049
Level/Trt x Per	4	0.413	0.103	1.275
Rep x Per	2	0.588	0.294	3.630
Sex	1	0.120	0.120	1.481
Final weight	1	2.218	2.218	27.380
Error b	49	3.977	0.081	
Total	78	52.837	0.677	

*Significant at .05 level of probability.

**Significant at .01 level of probability.

Table A-6. ANOVA for Broiler Mortality

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Statistics
Treatment	2	0.032	0.016	0.088
Level/Trt	4	0.444	0.111	0.613
Replicate	2	0.278	0.139	0.659
Error a	12	2.167	0.181	
Period	3	3.394	1.131	5.360*
Trt x Per	6	1.270	2.212	1.005
Level/Trt x Per	12	2.445	0.204	0.966
Rep x Per	6	2.256	0.376	1.782
Trt x Rep x Per	12	1.444	0.120	0.569
Error b	24	5.055	0.211	
Total	83	18.785	0.226	

*Significant at .01 level of probability.

APPENDIX B

Analysis of Variance (ANOVA) Tables for Broiler Feeding Experiment II

Table B-1. ANOVA for Broiler Final Weight

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Statistics
Treatment	2	46426.894	23213.447	9.772
Level/Trt	4	14451.457	3612.846	4.94
Trt x Rep (error a1)	2	4751.131	2375.565	3.248
Level/Trt x Rep (error a2)	4	2925.608	731.402	
Replicate	1	2806.471	2806.471	1.039
Methionine	1	9393.058	9393.058	3.477
Trt x Methionine	2	6513.036	3256.518	1.206
Rep x Methionine	1	920.535	920.535	0.341
Trt x Rep x Methionine	2	911.374	455.687	0.169
Sex	1	814019.394	814019.394	301.354
Initial weight	1	6.219	6.219	0.002
Error	34	91840.962	2701.205	
Total	55	994966.139	18090.293	

Table B-2. ANOVA for Broiler Body Weight Gain

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Statistics
Treatment	2	43173.856	21586.928	9.203
Level/Trt	4	18837.964	4709.491	6.894*
Trt x Rep (error a1)	2	4691.379	2345.690	3.434
Level/Trt x Rep (error a2)	4	2732.457	683.114	
Replicate	1	1913.685	1913.685	0.764
Methionine	1	11437.745	11437.745	4.566*
Trt x Methionine	2	7968.515	3984.257	1.590
Rep x Methionine	1	1570.719	1570.719	0.627
Trt x Rep x Methionine	2	1477.645	738.827	0.295
Sex	1	824784.405	824784.405	329.240**
Error	35	87679.041	2505.115	
Total	55	1006267.420	18295.771	

*Significant at .05 level of probability.

**Significant at .01 level of probability.

Table B-3. ANOVA for Broiler Feed Consumption Per Bird

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Statistics
Treatment	2	19980.582	9990.291	4.191
Level/Trt	4	25268.053	6317.013	2.650
Error a	6	14301.921	2383.654	
Replicate	1	96.034	96.034	0.000045
Methionine	1	17010.102	17010.102	0.008
Trt x Methionine	2	114.915	57.458	0.000027
Rep x Methionine	1	7236.825	7236.825	0.0034
Trt x Rep x Methionine	2	5175.323	2587.662	0.0012
Error b	36	76163519.290	2115653.314	
Total	55	76252703.050	1386412.783	

Table B-4. ANOVA for Broiler Feed Conversion

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Statistics
Treatment	2	0.011	0.005	5.00
Level/Trt	4	0.003	0.001	1.00
Replicate	1	0.001	0.001	0.001
Error a	6	0.006	0.001	
Methionine	1	0.001	0.001	0.001
Trt x Methionine	2	0.003	0.002	0.002
Rep x Methionine	1	0.001	0.001	0.0005
Trt x Rep x Methionine	2	0.001	0.001	0.0004
Error b	36	40.784	1.133	
Total	55	40.811	0.742	

Table B-5. ANOVA for Broiler Pancreas Weights

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Statistics
Treatment	2	0.401	0.200	0.913
Level/Trt	4	0.713	0.178	2.094
Trt x Rep (error al)	2	0.439	0.219	2.576
Level/Trt x Rep (error a2)	4	0.339	0.085	
Replicate	1	0.127	0.127	1.233
Methionine	1	0.613	0.613	5.951*
Trt x Methionine	2	0.106	0.053	0.515
Rep x Methionine	1	0.020	0.020	0.194
Trt x Rep x Methionine	2	0.157	0.079	0.767
Sex	1	0.002	0.002	0.019
Final weight	1	1.234	1.234	11.981**
Error	34	3.492	0.103	
Total	55	7.643	0.139	

*Significant at .05 level of probability.

**Significant at .01 level of probability.

Table B-6. ANOVA for Broiler Mortality

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Statistics
Treatment	2	1.048	0.524	0.50
Level/Trt	4	0.417	0.104	4.952
Trt x Rep (error a1)	2	2.095	1.048	49.905*
Level/Trt x Rep (error a2)	4	0.084	0.021	
Replicate	1	0.833	0.833	3.267
Methionine	1	0.133	0.133	0.522
Trt x Methionine	2	0.667	0.333	1.306
Rep x Methionine	1	0.133	0.133	0.522
Trt x Rep x Methionine	2	0.667	0.333	1.306
Error b	36	9.166	0.255	
Total	55	15.243	0.277	

*Significant at .01 level of probability.

APPENDIX C

Analysis of Variance (ANOVA) Tables for Consumer Taste Panel Scores

Table C-1. ANOVA for Broiler Meat Color

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Statistics
Treatment	2	0.231	0.115	2.881
Replicate	1	0.007	0.007	0.166
Meat type	1	0.735	0.735	18.346*
Rep x Trt	2	0.291	0.145	3.63
Rep x Meat type	1	0.027	0.027	0.666
Trt X Meat type	2	0.168	0.084	2.09
Sex	1	0.06	0.06	1.498
Error	13	0.521	0.04	
Total	23	2.038	0.089	

*Significant at .01 level of probability.

Table C-2. ANOVA for Broiler Meat Odor

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Statistics
Treatment	2	0.041	0.02	0.347
Replicate	1	0.327	0.327	5.557*
Meat type	1	0.002	0.002	0.028
Rep x Trt	2	0.036	0.018	0.305
Rep x Meat type	1	0.042	0.042	0.709
Trt x Meat type	2	0.036	0.018	0.305
Sex	1	0.167	0.167	2.835
Error	13	0.764	0.059	
Total	23	1.413	0.061	

*Significant at .05 level of probability.

Table C-3. ANOVA for Broiler Meat Flavor

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Statistics
Treatment	2	0.203	0.101	4.151*
Replicate	1	0.05	0.05	2.067
Meat type	1	0.000	0.000	0.017
Rep x Trt	2	0.001	0.000	0.017
Rep x Meat type	1	0.02	0.02	0.837
Trt x Meat type	2	0.241	0.12	4.937*
Sex	1	0.034	0.034	1.384
Error	13	0.317	0.024	
Total	23	0.866	0.038	

*Significant at .05 level of probability.

Table C-4. ANOVA for Juiciness of Broiler Meat

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Statistics
Treatment	2	0.116	0.058	0.635
Replicate	1	0.602	0.602	6.596*
Meat type	1	1.815	1.815	19.897**
Rep x Trt	2	0.01	0.005	0.059
Rep x Meat type	1	0.015	0.015	0.164
Trt x Meat type	2	0.548	0.274	3.001
Sex	1	0.007	0.007	0.073
Error	13	1.186	0.091	
Total	23	4.298	0.187	

*Significant at .05 level of probability.

**Significant at .01 level of probability.

Table C-5. ANOVA for Broiler Meat Tenderness

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Statistics
Treatment	2	2.643	1.322	33.175**
Replicate	1	0.12	0.12	3.023
Meat type	1	1.000	1.000	25.111**
Rep x Trt	2	0.003	0.002	0.042
Rep x Meat type	1	0.05	0.05	1.265
Trt x Meat type	2	0.303	0.152	3.807*
Sex	1	0.02	0.02	0.512
Error	13	0.518	0.04	
Total	23	4.66	0.203	

*Significant at .05 level of probability.

**Significant at .01 level of probability.

Table C-6. ANOVA for Broiler Meat Overall Acceptability

Sources of Variance	Degrees of Freedom	Sum of Squares	Mean Square	F Statistics
Treatment	2	0.111	0.055	1.370
Replicate	1	0.135	0.135	3.338
Meat type	1	0.027	0.027	0.659
Rep x Trt	2	0.077	0.039	0.958
Rep x Meat type	1	0.060	0.060	1.483
Trt x Meat type	2	0.521	0.260	6.438*
Sex	1	0.042	0.042	1.03
Error	13	0.526	0.04	
Total	23	1.498	0.065	

*Significant at .05 level of probability.

Table C-7. ANOVA for Broiler Meat Overall Ranking

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Statistics
Treatment	2	2.683	1.341	10.362*
Replicate	1	0.002	0.002	0.019
Meat type	1	0.002	0.002	0.019
Rep x Trt	2	0.54	0.27	2.086
Rep x Meat type	1	0.002	0.002	0.016
Trt x Meat type	2	3.904	1.952	15.077*
Sex	1	0.002	0.002	0.016
Error	13	1.683	0.129	
Total	23	8.819	0.383	

*Significant at .01 level of probability.

APPENDIX D

Analysis of Variance (ANOVA) Tables for Layer Feeding Experiment III

Table D-1. ANOVA for Total Number of Eggs

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F Statistics
Treatment	2	40.335	20.168	0.416
Level/Trt	4	193.292	48.323	0.996
Replicate	3	5.701	1.900	7.950*
Error a	17	824.706	48.512	
Period	4	14.047	3.512	14.695**
Trt x Per	8	44.061	5.508	23.046**
Level/Trt x Per	16	137.997	8.625	36.088**
Rep x Per	12	103.698	8.642	36.159**
Trt x Rep x Per	24	147.447	6.144	25.707**
Bird	7	297.872	42.553	178.046**
Trt x Bird	14	218.275	15.591	65.234**
Rep x Bird	21	355.114	16.910	70.753**
Level/Trt x Bird	28	396.808	14.172	69.297**
Error b	5	1.193	0.239	
Total	165	2780.546		

*Significant at .05 level of probability.

**Significant at .01 level of probability.

Table D-2. ANOVA for Hen-Day Egg Production

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Statistics
Treatment	2	317.088	158.544	0.718
Level/Trt	4	870.787	217.697	0.986
Replicate	3	1346.568	454.856	53.693*
Error a	17	3754.47	220.851	
Period	4	1587.465	396.866	46.800**
Trt x Per	8	371.732	46.466	5.479**
Level/Trt x Per	16	259.733	16.233	1.914*
Rep x Per	12	244.085	20.340	2.399*
Trt x Rep x Per	24	967.087	40.295	4.750**
Error b	41	347.780	8.480	
Total	131	10084.80		

*Significant at .05 level of probability.

**Significant at .01 level of probability.

Table D-3. ANOVA for Hen-Housed Egg Production

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Statistics
Treatment	2	375.452	187.726	0.763
Level/Trt	4	417.342	104.336	0.364
Replicate	3	1091.770	363.923	427.140*
Error a	17	4184.130	246.130	
Period	4	2168.346	542.086	636.250*
Trt x Per	8	283.125	35.391	41.540*
Level/Trt x Per	16	422.115	26.382	30.965*
Rep x Per	12	250.395	20.866	24.491*
Trt x Rep x Per	24	1191.656	49.652	58.277*
Error b	53	45.151	0.852	
Total	143	16864.000		

*Significant at .01 level of probability.

Table D-4. ANOVA for Layer Feed Consumption

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Statistics
Treatment	2	201.945	100.973	0.494
Level/Trt	4	554.157	138.539	0.678
Replicate	3	894.294	298.098	12.780**
Error a	18	3677.281	204.293	
Period	4	7215.088	1803.772	77.32**
Trt x Per	8	512.389	64.049	2.745*
Level/Trt x Per	16	571.504	35.719	1.531
Rep x Per	12	435.912	36.326	1.557
Trt x Rep x Per	24	307.615	12.817	0.549
Error b	48	1119.829	23.330	
Total	139	15490.010		

*Significant at .05 level of probability.

**Significant at .01 level of probability.

Table D-5. ANOVA for Layer Feed Efficiency

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Statistics
Treatment	2	0.561	0.280	0.981
Level/Trt	4	0.988	0.247	0.865
Replicate	3	0.706	0.235	8.704*
Error a	18	5.135	0.285	
Period	4	6.069	1.517	56.190*
Trt x Per	8	0.441	0.055	2.037
Level/Trt x Per	16	0.715	0.045	1.667
Rep x Per	12	0.284	0.024	0.889
Trt x Rep x Per	24	0.759	0.032	1.185
Error b	48	1.283	0.027	
Total	139	16.941		

*Significant at .01 level of probability.

Table D-6. ANOVA for Layer Pancreas Weight

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Statistics
Treatment	2	62.235	31.118	1.732
Level/Trt	4	324.605	81.151	4.516*
Replicate	3	50.997	16.992	0.802
Error a	18	323.418	17.968	
Bird	2	164.094	82.047	3.873*
Body weight	2	124.262	62.131	2.933
Error b	51	1080.541	21.187	
Total	82	2130.152		

*Significant at .05 level of probability.

Table D-7. ANOVA for Layer Body Weight Gain

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Statistics
Treatment	2	13671.035	6835.517	0.097
Level/Trt	4	86611.505	21652.876	0.477
Replicate	3	351741.015	117242.005	4.028*
Trt x Rep (error a1)	6	422849.599	70474.933	
Level/Trt x Rep (error a2)	12	544510.763	45375.897	
Bird	7	551883.640	78840.52	2.709*
Trt x Bird	14	449494.370	32106.669	1.103
Rep x Bird	21	890165.362	42388.827	1.456
Level/Trt x Bird	28	957506.269	34196.652	1.175
Error	68	1979109.943	29104.558	
Total	165	6247542.501		

*Significant at .05 level of probability.

Table D-8. ANOVA for Layer Mortality

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Statistics
Treatment	2	0.052	0.026	0.366
Level/Trt	4	0.222	0.055	1.486
Replicate	3	0.227	0.076	1.041
Trt x Rep (error a1)	6	0.424	0.071	
Level/Trt x Rep (error a2)	12	0.441	0.037	
Period	4	0.480	0.120	1.644
Trt x Per	8	0.948	0.118	1.616
Level/Trt x Per	16	1.161	0.073	1.0
Rep x Per	12	0.773	0.064	0.877
Trt x Rep x Per	24	1.529	0.064	0.877
Error b	48	3.526	0.073	
Total	139	9.783		

APPENDIX E

Analysis of Variance (ANOVA) Table for Urease Activity Measurement by Increase in P^H

Table E-1. ANOVA for Urease Activity Measured by Change in P^H

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Statistics
Soy type	3	49.398	16.466	1781.405*
Replicate	3	0.170	0.057	6.145*
Trt x Rep	9	0.290	0.032	3.491*
Error	48	0.444	0.009	
Total	63	50.302	0.798	

*Significant at .01 level of probability.

APPENDIX F

Tables of Means and Standard Errors for Various Broiler Parameters by Periods--Broiler Experiment I

Table F-1. Broiler Mean Weights and Standard Errors in Grams by 14-Day Periods[1]--Experiment I

	Dietary Regimen						
	SBM Control Diet.	10% Boilsoy Diet.	20% Boilsoy Diet.	30% Boilsoy Diet.	10% Roastsoy Diet.	20% Roastsoy Diet.	30% Roastsoy Diet.
Period 1							
Means	295.4	295.0	302.8	292.4	303.1	302.6	294.4
SE	12.9	16.0	16.2	13.9	12.9	12.8	15.0
Period 2							
Means	899.6	898.5	923.5	884.4	881.5	900.5	860.6
SE	68.9	70.0	64.8	80.2	61.1	71.0	75.5
Period 3							
Means	1608.3	1580.2	1649.6	1603.4	1639.7	1538.0	1865.0
SE	165.6	152.3	170.7	168.2	181.0	127.2	806.8
Period 4							
Means	2165.5	2169.3	2212.2	2192.6	2208.5	2057.3	2129.4
SE	271.8	204.8	260.2	214.2	234.0	147.9	255.0

[1]Period 4 lasted only 10 days.

Table F-2. Broiler Mean Feed Consumption and Standard Error of Means in Grams Per Bird by 14-Day Periods[1]--Experiment I

	Dietary Regimen						
	SBM Control Diet.	10% Boilsoy Diet.	20% Boilsoy Diet.	30% Boilsoy Diet.	10% Roastsoy Diet.	20% Roastsoy Diet.	30% Roastsoy Diet.
Period 1							
Means	344.9	342.6	347.1	337.8	335.5	342.7	321.3
SE	10.8	8.2	24.4	10.8	4.1	14.6	10.8
Period 2							
Means	895.4	871.8	872.4	850.5	881.2	877.6	843.4
SE	4.1	24.6	59.1	25.6	32.7	27.7	7.1
Period 3							
Means	1422.7	1467.9	1465.7	1416.1	1509.0	1362.8	1400.4
SE	74.0	32.6	115.7	18.1	93.7	52.3	45.0
Period 4							
Means	1478.0	1480.6	1421.7	1419.6	1495.1	1349.2	1422.8
SE	28.1	83.3	128.7	39.2	74.5	12.9	42.7

[1]Period 4 lasted only 10 days.

Table F-3. Broiler Cumulative Feed Conversion and Standard Error of Means in Grams Feed Per Gram of Gain by 14-Day Periods[1]--Experiment I

	Dietary Regimen						
	SBM Control Diet.	10% Boilsoy Diet.	20% Boilsoy Diet.	30% Boilsoy Diet.	10% Roastsoy Diet.	20% Roastsoy Diet.	30% Roastsoy Diet.
Period 1							
Means	1.34	1.33	1.31	1.32	1.29	1.29	1.25
SE	.017	.025	.038	.031	.025	.038	.052
Period 2							
Means	1.44	1.41	1.38	1.40	1.45	1.42	1.42
SE	.01	.012	.006	.035	.029	.01	.064
Period 3							
Means	1.64	1.68	1.65	1.62	1.70	1.66	1.66
SE	.038	.035	.032	.025	.038	.027	.021
Period 4							
Means	1.95	1.94	1.89	1.87	1.94	1.95	1.91
SE	.032	.011	.020	.051	.055	.027	.029

[1]Period 4 lasted only 10 days.

Table F-4. Broiler Mean Pancreas Weights and Standard Error of Means in Grams by Periods[1]--Experiment I

	Dietary Regimen						
	SBM Control Diet.	10% Boilsoy Diet.	20% Boilsoy Diet.	30% Boilsoy Diet.	10% Roastsoy Diet.	20% Roastsoy Diet.	30% Roastsoy Diet.
Period 1							
Means	2.32	2.14	2.05	1.89	1.97	2.24	2.11
SE	.18	.30	.33	.17	.26	.40	.17
Period 2							
Means	3.68	3.87	3.78	3.57	4.11	3.73	3.68
SE	.62	.45	.44	.41	.71	.35	.64

[1]Period 1 lasted 28 days, while period 2 lasted 24 days.

Table F-5. Broiler Chicks Mortality by 14-Day Periods for Experiment I (Actual Number of Deaths)

	Dietary Regimen						
	SBM Control Diet.	10% Boilsoy Diet.	20% Boilsoy Diet.	30% Boilsoy Diet.	10% Roastsoy Diet.	20% Roastsoy Diet.	30% Roastsoy Diet.
Period 1	0	0	1	0	0	1	0
2	0	0	0	0	0	0	0
3	3	1	1	1	2	1	1
4	0	1	0	2	1	0	1
Totals	3	2	2	3	3	2	2

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