INFLUENCE OF PROCESSING ON THE FEEDING VALUE OF COTTONSEED MEAL

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INTRODUCTION

Cottonseed meal and soybean meal are the two principal vegetable protein concentrates produced in the United States. Even before the development of the soybean industry, cottonseed meal was being used on a large scale as a livestock feed. Results of recent experimental work indicate that cottonseed meal, when properly processed, is as valuable as soybean meal as a protein concentrate for poultry.

Processing conditions have been found to affect the nutritive value of cottonseed meal. Early in 1917, Carruth observed that the amount of gossypol which could be extracted with diethyl ether decreased markedly when the cottonseed was cooked. Later, the theory of bound gossypol was proposed. (Winters and Carruth, 1915; Carruth, 1917; and Clark, 1928). According to this theory, gossypol is rendered inactive during cooking by combining with the amino acids of the surrounding seed tissue. On the other hand, the protein quality of cottonseed meal is seriously injured by excessive heating.

Much research has been done during the last few years for the purpose of learning more about the effect of processing upon the biological value of cottonseed meal. Although considerable progress has been made, further investigations are still required.

The objectives of this work are:

(a) To study the growth response of chicks fed samples of cottonseed meal which have been subjected to different conditions of processing.

(b) To determine the tolerance of young chicks for cottonseed meal which has been processed under conditions conducive to the maintenance of high protein quality and to the maximum inactivation of gossypol.

(c) To determine the amount of soybean meal which can be replaced successfully by commercial cottonseed meal in a broiler ration.

REVIEW OF LITERATURE

Nutritive Value of the Cottonseed Meal Protein — The feeding value of cottonseed meal and cake as a source of protein of good quality for livestock and poultry has been recognized for many years. On the basis of amino acid content the cottonseed meal protein compares favorably with that of soybean meal. Cottonseed meal is deficient in lysine, but contains high levels of the other essential amino acids. This deficiency in lysine has been suggested to be involved in the occurrence of white feathering in chicks fed diets high in cottonseed meal (Milligan and Bird, 1951). Apparently a deficiency in lysine constitutes one serious limitation to the use of cottonseed meal as the only source of protein for poultry, since most of the vegetable feedstuffs, with exception of soybean meal, are low in that amino acid.

Feeding trials for the purpose of determining the nutritive value of cottonseed meal have been made by many investigators. Early in 1914, Hartwell and Lichtenthaeler demonstrated the value of cottonseed meal as a source of protein in the ration of chicks. Morgan (1931) found that good results were obtained when half of the animal protein was replaced by cottonseed meal in laying hen rations. Berry (1934) reported that in chick grower rations containing ten percent of dried buttermilk, cottonseed meal can supply the added protein as efficiently as meat and bone scraps.

More recently, Heywang (1947) reported a feeding trial in which cottonseed and soybean meals were compared as sources of vegetable protein for laying hens. It was concluded that these two proteins have about the same nutritive value as measured by relative egg production, feed consumption, body weight, and mortality.

According to Sherwood and Couch (1939) cottonseed meal and soybean meal may be used interchangeably in chick rations.

Many other studies have been conducted, notably at the southern stations (New Mexico, 1918, 1930, Texas, 1924, South Carolina, 1931, and Oklahoma, 1943). In general, the results indicate that cottonseed meal can successfully replace part of the animal protein in the diet of layers and growing chicks. Contradictory results obtained by some stations, apparently, are due to differences in the quality of the meals or the failure to use a standard basal ration in all feeding experiments.

Toxic Materials of the Cottonseed Meal -- The presence of a toxic substance in cottonseed has been demonstrated. (Winters and Carruth, 1915, and others). At present, it seems positively established that all the toxic compound or compounds are segregated in the pigment gland of the seed. These glands which are very peculiar and characteristic of all the species of the genus Gossypium are profusely distributed in the seed tissue. The outer structure of the pigment gland has been found to be a thick and rigid wall which presumably protects the extremely active and unstable polyphenolic pigments in the gland. The glands are very resistant to mechanical agents but sensitive to the action of water and other organic liquids of low molecular weight such as miscible alcohols, ketones and ethers. The effect of water is moderately increased by heating. Contact with moisture produces an immediate rupture of the gland walls.

Gossypol is the principal intraglandular pigment of the cottonseed. It is a yellow solid, soluble in several organic solvents and insoluble in low boiling petroleum naptha and water. About forty percent of the weight of the pigment glands and three percent of the seed consists of gossypol. Prolonged heating at a temperature slightly above the melting point results in the decomposition of gossypol with the elimination of one molecule of water and the formation of an orange colored compound designated as anhydrogossypol.

The results of different studies fail to agree as to the temperature necessary for decomposition, However, Clark (1928) has found that gossypol preparations having widely different decomposition temperatures were identical with respect to other properties.

The destruction of gossypol by heating was reported early in 1915 by Winters and Carruth, who found that cottonseed meals from cooked seeds had a lower content of ether extractable gossypol. Later it was found that the gossypol of cooked seeds could be extracted by treatment with warm aniline. This gossypol has been referred to as bound gossypol. By contrast, the ether extractable gossypol is called free gossypol.

Winters and Carruth (1917) reported that the amount of ether extractable gossypol decreases as the amount of gossypol extractable with aniline increases, and as the cooking is prolonged.

At present free gossypol is defined as the amount of gossypol that is readily extractable by aqueous acetone according to the method developed by Pons and Guthrie (1949).

The explanation of the decrease of free gossypol by cooking is based upon the theory of bound gossypol. According to this theory, gossypol reacts with the free amino acids and free carboxyl groups of cottonseed protein under the influence of heat.

Gossypurpurin, another cottonseed pigment was isolated by Boatner (1944). It is purple colored and is found at a very low concentration. It constitutes less than one percent of the weight of the glands. Solutions of gossypurpurin are unstable to light and heat. Gossypol can be converted to gossypurpurin.

Recently, interest has been shown in gossycaerulin, a blue pigment found in cooked seeds. Apparently it is derived from gossypol during the heating of the cottonseed meats. No gossycaerulin has been found in raw cottonseed.

Boatner and co-workers (1944) have isolated from ethereal extract of cottonseed an orange colored pigment designated as gossyfulvin. It has been reported that gossyfulvin can be converted directly to gossypol by treatment with acid. Probably the high sensitivity of gossyfulvin to the action of heat explains why it has not been found in cooked seeds.

Toxicity of Gossypol -- The deleterious effect of uncooked cottonseed meals on the growth of chicks, hatchability and egg quality has long been attributed to gossypol. However, according to recent investigations, other components of the pigment gland may be involved.

Boatner and associates (1948) reported that pure gossypol added to the diet produces relatively little retardation of the growth of chicks, and poor correlation was found between the nutritional values of various cottonseed products and their contents of gossypol and gossypurpurin.

Olcott (1948) concluded from his feeding test with rats that the toxic factors of the cottonseed meal can be nulified by three apparently unrelated mechanisms: air oxidation, combination with soluble iron salts and destruction by steam autoclaving.

Lillie and Bird (1950) presented the results of oral administration of pure gossypol and pigment glands of cottonseed on mortality and growth of chicks. Toxicity of gossypol administered by capsul was compared with the toxicity of pigment glands administered by capsule. It was found that pure gossypol and pigment glands administered at levels which supplied equivalent quantities of gossypol have about the same effect on mortality and growth of chicks.

The reason for the apparent contradictory results obtained by Lillie and Bird (1950) and Boatner and associates (1948) can be explained on the basis of the destruction or inactivation of gossypol when incorporated in the feed mixture. This explanation, which has been suggested by Lillie and Bird, is in accordance with the conclusions of Olcott (1948) relating to the destruction of gossypol by air oxidation.

Confirming the conclusions of Lillie and Bird (1950), Heywang and his colleagues have recently demonstrated that large portions of the gossypol are destroyed or rendered inactive after a short time when mixed into a ration. They fed three groups of pullets with diets to which had been added 0.012, 0.024, or 0.036 percent of gossypol. The mixed diets were fed only the sixth and seventh days after mixing. No decrease on hatchability was noted when gossypol was mixed in the diet at the .012 and 0.024 percent levels, and only a slight decrease was observed at the 0.036 percent level.

at the 0.036 percent level.

Accurate figures on the minimum levels of free gossypol which have an adverse effect on growth of chicks, hatchability and egg quality are still unknown. Some studies have been conducted on this subject but the data obtained, in general, does not agree. Recent investigations indicate that the maximum level of free gossypol for growing chicks is about .04 percent (Heywang, 1951). For laying hens the figures seem to be somewhere between .002 and 0.009 percent of the diet. (Heywang, 1951, Stephenson, 1951, and Morgan, 1951).

Determination of Gossypol in Cottonseed Products: — Many methods of analyzing for gossypol have been proposed (Carruth, 1917; Schwartze, and Alsberg, 1923, and others). However, most of them are based on the reaction of extracted gossypol with aniline. Dianiline is formed and the amount determined by gravimetric or spectrophotometric methods. Quantitative estimations by spectrophotometric methods are, in general, based on the measurement of the absorption spectrum of dianiline gossypol.

Boatner and associates (1944) have suggested the antimony trichloride method for the determination of gossypol on extracts of cottonseed or cottonseed meals. It is based upon the absorption spectrum of the stable reaction product which antimony trichloride forms with gossypol in chloroform.

The extraction of free gossypol is accomplished by diethyl ether or aqueous acetone which are able to rupture the pigment glands without, apparently, reacting with the pigments.

Recently a new spectrophotometric method for gossypol determination has been described by Pons and Guthrie (1949). It is based on the color produced by the reaction product of the aqueous acetone extracted gossypol with P-anisidine. Determination of total gossypol can be carried out by the same method after hydrolysis of bound gossypol with oxalic acid in aqueous methyl ethyl ketone.

The current methods for gossypol estimation, measure gossypol and the closely related compounds which form with P-anisidine or aniline products spectrophotometrically identical with that of pure gossypol.

Effect on the Egg Quality:-- One of the most serious problems associated with the use of cottonseed meal in the laying hen rations is its undesirable effect upon egg quality. If more than thirty percent of cottonseed meal is added to the diets, the yolks may show cottonseed spots. If percentages between eight and thirty are used, yolks of fresh eggs are normal in color, but if the eggs are kept in storage, the yolks tend to acquire olive color. Abnormal enlarged yolks and pink whites are also reported to be found in eggs from hens fed cottonseed meal.

Results of several studies show that cottonseed meal up to six to eight percent of the ration has no bad effect on the quality of eggs. Many experiments have been conducted in order to determine the cause of this condition. However, further investigations are still required.

Most of the workers agree that gossypol, the principal pigment of cottonseed, is the main factor involved in the yolk discoloratiom.

Schaible, Moore, and Moore (1934) concluded from their work that either free gossypol or bound gossypol may bring about abnormal yolk color. It was also found that ferrous sulphate added to the diet containing forty percent of cottonseed meal prevents the occurrence of olive yolks.

Experimental work conducted by Kuiben et. al., (1948) indicated that bound gossypol apparently has no effect in yolk coloring. Lorenz and Almquist (1935) and Lorenz (1935) have demonstrated that the pink color of albumin is caused by an unidentified substance in cottonseed meal which is not gossypol.

An experiment conducted at the California station (1939) indicated that the deterioration of eggs which results from feeding cottonseed meal is caused by two distinct substances which have separate effects on the eggs. Gossypol gives the yolk an olive green color and gelatineous consistency. The other substance which is either identical with or closely associated with the Halphen substance, causes an abnormal enlargement of the yolk and the development of reddish color in the albumin while the eggs are in storage.

Swensen and co-workers (1942) presented evidence that the olive color of the yolks is due to the chemical combination of gossypol from cottonseed meal with ferric ions released from the yolk proteins. The authors indicated also that the addition of soluble ferric salts to a ration containing cottonseed meal prevents the absorption of the gossypol by the hen and the formation of olive colored yolks in stored eggs.

The effect of the iron salts upon gossypol has also been determined in swine and guinea pigs which have their tolerance for gossypol increased when these salts are added to the ration.

Stephenson and Smith (1952) of the Arkansas station, were able to keep eggs from hens fed twenty percent of the experimental screw pressed cottonseed meal, for a period of six months without any detrimental effects in egg quality.

<u>Effect on Hatchability and Egg Weight</u>: — The adverse effect of cottonseed meal on hatchability and egg size has been reported by many stations (Oklahoma, 1917; Alabama, 1927; New Mexico, 1930; and others). Occurrence of these undesirable effects has been attributed to the action of gossypol.

Heywang and associates (1949) found that ten percent of either hydraulic or solvent cottonseed meal may be included in the diet of breeders with no adverse effect on the hatchability, if the meals do not contain more than .12 percent of gossypol. The authors believed that components of the pigment gland other than free gossypol may have adversely affected hatchability in their experiment, but these components apparently increased as the gossypol increased.

<u>Processing of Cottonseed</u>: — Commercial cottonseed oil is extracted by hydraulic, expeller and solvent processes. More than ninety percent of the cottonseed of the United States is processed by hydraulic pressing.

The solvent process which is already largely used for extraction of oil from soybeans has been found to increase the oil yield of cottonseed (Alderbs, 1948). The undesirable dark colored oil and

and the high free gossypol content of the meal obtained by commercially available solvents are the most serious limitations to this process.

Alderbs (1948) in discussing the studies of Leahy (1939) and others states that saving in labor, better press room efficiency, detoxification of the meals and elimination of the cost of the press cloth are the advantages of the expeller or screw processing as compared with the usual hydraulic presses.

Both in hydraulic and in screw methods, cottonseeds are decorticated, rolled and cooked before the pressing operation. The purposes of cooking are to rupture or finish rupturing the oil cells, to increase fluidity of the oil, to coagulate the proteins to facilitate oil purification, to dry the meats to a proper moisture content, to inactivate gossypol, and to destroy molds and bacteria. No advantage has been found in cooking seeds when solvent processes are used, in so far as the yield and quality of the oil are concerned.

As the quality of oil and meal is closely related with the heating of the seeds, the determination of adequate cooking conditions is a very important factor in industrial operation. Some years ago, cooking of the meal was considered an art since the physical factors involved in it were determined by trained operators. At present, most of the oil mills have definite methods for controlling cooking conditions.

Temperature, length of time of cooking, and the amount of water added to the seeds before and during cooking may vary greatly in different mills. Usually temperature in both hydraulic and screw pressing range up to 230°F or 240° F, and the duration of cooking is from thirty to sixty minutes.

In expeller processes, additional heat is produced by friction when the meats are forced continually through the screw press. The temperature at this time may go as high as 300°F.

For solvent extraction, cooking of the seeds is not necessarily required. However, sometimes a combination of solvent extraction and pre-pressing is used. In this case, the flaked meats are cooked and then pressed to reduce the amount of oil to about ten percent. The remaining oil is removed by solvent extraction which secures higher yields. Variations in the conditions of cooking have been mentioned as the most important factor responsible for different characteristics in different samples of the commercial meals.

In addition to the industrial methods of processing cottonseeds, several laboratory methods have been developed. Boatner and Hall (1946) have recently developed the gland floatation process which makes possible the mechanical removal of glands intact from defatted meals. It is based on the difference in the density of the pigment glands and other seed tissues, and on the extreme resistency of the glands to the tremendous pressure which the meats are subjected during the rolling operation. The glands are first disengaged from the surrounding seed tissues by the violent agitation of a suspension of flaked kernels in a solvent or mixtures of solvents which do not attack the pigment gland walls. After disintegration of the flaked seeds, the density of the solution can be adjusted in such a way that the glands can float to the surface and be mechanically separated from the dissolved oil and the precipitated gland-free tissues. After this procedure the residual meal is mechanically separated from the miscella and the oil is freed of solvent by the usual methods. If glands, essentially free of adhering tissues, are desired for study purposes, a more prolonged agitation and further treatment are required. The usual procedure consists of suspending the glands with finely divided silic (300 mesh) in a hydrocarbon solvent and agitating vigorously.

Several organic liquids can be used in the floatation process, but commercial hexane and perchloroethylene have been reported to be the most desirable (Wise, Spadaro, Westbrook, Crovetto Pollard, and Gastrock, 1947).

Detoxification of the Meals by Processing: — As previously pointed out, cooking of the seeds has a definite influence on the detoxification of the meals. This effect has been attributed to changes in the chemical composition of the pigment gland content. To date, much stress has been laid on the combination of gossypol with the proteins of the seed. However, other pigments present in the gland in lesser amounts may be involved.

Winters and Carruth (1915) were the first to note that the amount of free gossypol in the cooked seeds decreases as the warm aniline extractable gossypol increases.

Lyman and co-workers (1944) of the Texas station demonstrated that while the free gossypol can be markedly reduced by processing, the total gossypol remains about the same. It was also observed that the amount of free gossypol depends to a large extent upon the temperature and water added to the meat before cooking. Toxicity of the meal was tested on guinea pigs which are very sensitive to gossypol intoxication. The results indicated that practically all toxic material of wet cooked seeds was inactivated. By contrast, meals from dry cooked seeds were very toxic.

Boatner and colleagues (1947) have reported that the amounts of ether extractable gossypol decrease faster during cooking in moistened than in unmoistened seeds. However, after prolonged heating the gossypol content of dry cooked seeds falls to about the same level as that in wet cooked kernels.

The influence of moisture can be explained on the basis of the extreme sensitivity of the pigment gland wall to the action of water.

Boatner and others (1948) have studied the effects of different parts of the cottonseed on the growth of chicks as compared with that produced by a basal ration containing thirteen percent of screw pressed soybean meal. A very good rate of growth was obtained on the experimental rations containing gland-free cottonseed flour; uncooked, diethylether-extracted cottonseed and hydraulic pressed cottonseed meal. Significantly lower growth was observed on the rations containing uncooked, hexane-extracted cottonseed or pigment glands. These results, confirming previous investigations, show that the toxic substance of cottonseeds found in the pigment glands can be inactivated by cooking or extracted by di-ethyl ether. It was also demonstrated that hexane removes very little gossypol from the cottonseed meats.

In addition to the cooking or to the action of some solvents upon pigment glands, other physical or mechanical factors of processing may have a marked influence upon gossypol detoxification.

The results of recent studies (Haddon, Schwartz and Williams, 1950, and Milligan and Bird, 1951) emphaize the importance of energy input into the expeller press and the action of heat produced by friction in the screw presses.

Haddon, Schwartz, and Williams (1950) concluded from experimental work, that the energy input to the screw press is inversely proportional to the oil content, soluble nitrogen and percent of free gossypol. The data indicated that the free gossypol decreased from about .74 to .03 percent during the passage of the meals through the screw press.

Milligan and Bird (1951) stated that meals pressed with an energy input of fifty amperes contained more soluble nitrogen and in general were higher in feeding value than the ones pressed with and input of sixty amperes.

Recent investigations have shown that it is possible to obtain cottonseed meal very low in free gossypol and high in protein quality by screw presses. These studies are based on the possibility of increasing the number of pigment glands which are ruptured by pressure and shearing forces during pressing operation in screw presses. Apparently this can be done by better conditions of cooking, by control of the energy input to the press and by adequate rolling of the meats. Improved rolling techniques will make it possible to break a considerable portion of the glands before cooking and much less cooking will be required to rupture the remainder of the glands. Rupturing of the pigment gland walls brings out the gossypol which combines with other components of the meal forming bound gossypol.

Preliminary research (Altschul, 1951) demonstrated that high quality protein cottonseed meal as low as 0.03 percent in gossypol can be obtained by improved conditions of screw pressing.

A new method of chemical treatment of cottonseed meal has been recently applied by the Buckeye Cotton Oil Company at Augusta, Georgia. After oil extraction with commercial hexane the meals are treated with organic amine which reacts with gossypol and renderes it physiologically inactive. The product obtained in such a way is available on the market under the name of "degossypolized" cottonseed meal containing an amount of free gossypol no more than .04 percent.

Effect of Processing on the Nutritive Value of the Meals: — The feeding value of cottonseed meal, as a protein concentrate for chickens depends essentially upon the amount of intact protein and the percentage of free gossypol or gossypol-like materials it contains.

The biological value of cottonseed protein has been measured by several experimental methods including protein solubility, enzymatic hydrolysis, thiamine content and direct feeding trials on rats and farm animals.

The solubility test was first used by Olcott and Fontain (1942). They found a correlation between the solubility of cottonseed meal protein in a three percent sodium chloride solution, and its nutritive value. The nutritive value increased as the solubility increased.

Recently Ingram and co-worker (1950) have shown that the protein quality of cottonseed meal for chicks may be evaluated by enzymatic hydrolysis. A good correlation was found between the amount of certain amino acids released by enzymatic hydrolysis and the growth of chicks supported by samples of cottonseed meal. An apparent relationship between the gossypol content of the meals and the percentage of liberated amino acids was also observed. The authors suggest that the presence of toxic material in the cottonseed causes a retardation of the action of the proteolytic enzymes.

The thiamine content of cottonseed meal has been used recently as another way of determining the biological value of cooked cottonseed meals. This method is based on the reduction of thiamine content by heating. A low thiamine content would indicate that the meal was cooked under unfavorable conditions, since thiamine is destroyed by excessive heating.

It is definitely established that the processing of the meats may markedly affect these two factors. For this reason the main problem of the improvement of cottonseed meal quality consists in the removal or destruction of gossypol without detrimental effect upon the biological value of the protein.

Many studies have been conducted on the effect of cooking conditions on the quality of the proteins. Adequate heating improves the protein quality of legume seeds by destroying an anti-enzyme, trypsin inhibitor which is present in the beans. The same is not true with regard to cottonseed protein, which, according to experimental work can be injured by excessive cooking.

Olcott and Fontain (1942) demonstrated that cottonseed proteins are very sensitive to temperature changes above 105-110°C. The same authors have reported that heating cottonseed with steam under pressure reduces the utilization of the proteins. This condition affected also the solubility of the proteins in a three percent sodium chloride solution. The meals containing low soluble proteins showed reduced nutritive value. The solubility of proteins of commercial meals from different sources ranged from 5.9 to 9.2 percent in water and 9.6 to 46.7 percent in a three percent sodium chloride solution. This variation is related to conditions of cooking, since the high temperatures associated with high moisture cause denaturation of the proteins. The solubility of native proteins in salt solution is as high as ninety percent.

The exact effect of heating on the feeding value of the proteins is not known. Apparently, some amino acids, namely, lysine, arginine, tryptophan and histidine, are destroyed or rendered less biologically available. Ewing (1947) discussing the works of Almquist and others, states that the amount of lysine which can be found by analysis is not decreased as a result of heating. Furthermore, when heat damaged proteins are hydrolyzed by acids previous to feeding, they are found to have about the same biological value as the unheated hydrolyzed proteins, indicating that lysine has been made available again. According to more recent investigations, the cottonseed proteins on heating combine with reducing sugars or other chemical compounds in the meats and the amino acids are tied up. Also the rate of release of amino acids can be affected. If some amino acids are liberated more slowly than others, they will not be utilized efficiently for protein synthesis.

Milligan and Bird (1951) presented evidence that both the supply of available lysine and soluble nitrogen tend to decrease with an increase in temperature of cooking.

EXPERIMENT NO. I.

Material and Method:-- The nutritive value of commercial cottonseed meal has been found to vary markedly. Recently, a number of cottonseed meals produced by newer methods of processing have become available on the market. A study of the comparative nutritive value of six of these meals when fed to growing chicks during a four weeks growing period is reported in this experiment.

Day-old New Hampshire chicks of both sexes, supplied by the poultry farm at the Oklahoma Agricultural Experiment Station, were used in this study. The chicks were banded, weighed and vaccinated against Newcastle with intranasal vaccine. The experiment was run in triplicate, using fifteen chicks in each pen. All the birds were kept in electrically-heated batteries equipped with raised wire floors during the four week experimental period.

The word pen is used to identify the group of chicks brooded in one sepatate section of the battery and the word lot to designate all the chicks subjected to the same treatment. Each lot was composed of three pens. The lots were numbered from 1 through 7, and the pens from 1 through 21. The chicks were distributed into pens at random. Distribution of each pen into the different compartments of the battery was also made at random. Individual weights and records of feed consumption were taken at two week intervals. Feed and water were available at all time except for periods of about eight hours previous to each weighing. Daily observations were made and a record of mortality was kept. Feed efficiency was calculated by dividing the total pounds of feed consumed by the total pounds of gain. No deduction was made for the weight losses incurred due to mortality. At the end of the experiment the chicks were sexed. The average weight for each lot was determined by dividing the sum of the average weight of males and females by two.

Six different samples of cottonseed meals were added to a semi--purified basal diet containing all the vitamins and minerals required for growth. The composition of the basal and experimental diets is given in Table I. and that of the vitamin and mineral mixtures in Table II. Soybean oil was used in the basal to improve feed texture and to increase feed consumption. The addition of T-cake was made to increase the dietary level of leucine. No amino acid in pure form other than methionine was added. The calculated levels of amino acids of the diets used is given in Table V.

The experimental rations were composed of 85 percent of the basal and 15 percent of cottonseed meal. The control diet had 12.5 percent of soybean meal and 85 percent of basal. One and one--half pounds of cerelose were added to this ration to complete 100 units. Ten milligrams of procaine penicillin per pound of feed and 0.0125 percent of sulfaquinoxaline were added to all the diets. The rations were mixed fresh every two weeks. The trace minerals and the penicillin were dissolved separately in water before they were mixed into the feed. Sulfaquinoxaline was mixed with cerelose before it was incorporated into the ration. Samples for chemical analysis of the control and experimental rations were taken when the rations were mixed. The results of these analyses are shown in Table IV. The analyses of the cottonseed meals used, including gossypol, protein solubility and thiamin content are given in Table III.

The cottonseed meals used were supplied through the courtesy of the Western Cottonoil Company of Abilene, Texas. According to the processor, the following manufacturing procedures were used in the production of these meals.

Cottonseed Meal A and B: — "This is a prepress solvent extraction process. French screw presses are used.

The rolled meats pass through a French 5 high 72" cooker for a cooking time of approximately fifty minutes. The total moisture attained in the top ring is approximately 12 percent. The temperatures range from 195° F in the top ring to about 235° F in the bottom. Pre-press cake will contain from 9 percent to 11 percent oil and 6 to 9 percent moisture.

The meal coming from the driers in the solvent plant will be about 215° F. This meal is ground and sized for sacking by grinding with a hammer mill and bolting."

Cottonseed Meal C: — "This is a prepress solvent extraction process. Anderson prepress and solvent extraction equipment are used.

The rolled meats are sent to a D-K six high cooker. Moisture is added until a total of about 12 percent is attained in the top ring. The total cooking time is 90 to 120 minutes. The following approximate temperatures are attained in the cooker rings: 195° F, 200° F, 205° F, 210° F, 215° F, and 220° F.

A temperature of 230° F to 240° F is maintained in the conditioner just before prepressing. The oil and moisture in the pre-press cake are approximately 9 percent each. A temperature of 225° to 230° F is attained in the driers in the solvent plant.

The solvent meal is prepared for sacking by grinding in a hammer mill."

Cottonseed Meal D : — "The rolled meats are processed through a standard French 5 high 85" cooker using the continuous method of cooking. The total moisture of meats attained in the top ring is 12 percent to 14 percent. Total cooking time is about 90 minutes. The temperature ranges approximately as follows: 195° F, 218° F, 222° F, 226° F, and 230° F.

Pressing is accomplished on a standard hydraulic system of ten presses. Five presses are loaded every fifteen minutes. The finished cake moistures are from 7 percent to 8 percent. The cake is ground to meal on an attrition mill."

Cottonseed Meal E:— "Unrolled meats are routed through a double Anderson cooker arrangement where the meats are held for approximately 30 minutes and a temperature of 176° F is attained. These meats then go to five Anderson expellers. Four of these machines have the old Anderson three tube drier arrangement before pressing. The meats pass through this arrangement in approximately seven minutes and attain a temperature of approximately 260° F in the driers. The other expeller is equipped with a standard Anderson cooker and conditioner where the meats are held approximately twenty minutes and a temperature of approximately 260° F is attained.

The finished cake moisture is about 3 percent.

The cake is ground into meal on an attrition mill."

Cottonseed Meal T2: — This meal was also supplied by the Western Cottonoil Company of Abilene, Texas. Information about the manufacturing procedure used in its production was not available at the time this paper was written.

RESULTS AND DISCUSSION

The original purpose of this experiment was to determine the effects of processing conditions on the nutritional value of cottonseed meals. As this is just a preliminary investigation the experimental period was limited to four weeks.

Soybean meal was chosen as a control because it is one of the most adequate vegetable proteins from an amino acid standpoint. The results shown in Table VI indicate that the biological value of the cottonseed meal protein as measured by growth in chicks is about the same as that for soybean protein. The gains made by the chicks fed rations 2, 3, and 5 are equal to those made by chicks fed ration 1 (soybean meal). The growth response of ration 4 (cottonseed meal C) was somewhat better than the control and the experimental diets 2, 3, 5, and 6. However, the differences are not statistically significant.

The chemical analysis of the rations used indicates that the control ration was lower in protein than the experimental rations. Therefore, better results might be expected for lot 1 if the same levels of protein were fed. In addition, individual weights obtained for the soybean diet were quite variable. Mortality in all lots was negligible but a number of chicks from the three pens supplemented with soybean meal weighed considerably less than the average. If these chicks are taken out, the average weight for ration 1 is very close to that of ration 4. The rate of growth of the other lots was rather uniform. No apparent reason for the irregular response of ration 1 was found. This effect was observed in all three pens (pen numbers 2, 12, and 19) of this lot. Two chicks of the group fed the control ration were sick, with typical symptoms of Newcastle disease, at the end of the experiment.

The weight gain for Lot 6 (cottonseed meal E) was comparatively poor. Since the percentage of free gossypol in cottonseed meal E is lower than that in cottonseed meal C and since sample C gave better growth, it becomes evident that gossypol was not responsible for the lower growth rate for ration 6.

Evidence is available that the protein of cottonseed meal D was injured by processing. The data in Table III shows that this sample was of poor quality in so far as the total protein solubility and thiamin content was concerned. Also the information supplied by the manufacturer indicates that sample D was subjected to less favorable conditions of cooking.

The correlation found in this study between the growth response produced by sample D and its thiamin content is an indication that the thiamin test is an accurate method of measuring the protein quality of cottonseed meal.

As was pointed out before, the results provide ample evidence that gossypol did not have any measurable effect on rate of growth in this study. Table III shows that sample C has little more free gossypol than sample D which provided the lowest rate of growth. Therefore, it can be concluded that free gossypol in cottonseed meal at the level of 0.04 to 0.06 percent has no inhibitory effect on growth when 15 percent of cottonseed meal is fed in the ration.

As the cottonseed meal was deficient in lysine the addition of this amino acid to the diet might have improved the growth to some extent.

TABLE I

Composition of the basal and experimental rations

Basal

Component	Pounds
Cerelose	46.4
Soybean Meal (low fiber, 50% protein)	26.0
T-Cake (Wheat gluten hydrolysate)	1.0
D L Methionine	.1
Vitamin Mixture	5.0
Mineral Mixture	5.0
Soybean Oil	1.5

Experimental

Component	No.1 %	No.2 %	No.3 %	No.4 %	No.5 %	No.6 %	No.7 %
Basal	85.0	85	85	85	85	85	85
Soybean Meal	12.5	-	-	-	-	-	-
Cottonseed Meal	-	15(A)	15(B)	15(c)	15(D)	15(E)	15(T_2)
Cerelose	1.5	-	-	-	-	-	-

TABLE II

Mineral and vitamin mixture

Mineral	Percentage
$CaCo_3$	29.40
$CaHPO_4 \cdot 2H_2O$	32.58
K_2HPO_4	15.73
NaCl	11.24
$MgSO_4 \cdot 7H_2O$	9.36
$Fe_2(SO_4)_3$	1.03
$MnSO_4 \cdot 4H_2O$	0.54
KI	0.062
$CuSO_4$	0.028
$ZnCl_2$	0.018
$CoCl_2 \cdot 6H_2O$	0.0037
Vitamin	**Amount**
Feeding A oil (6000 I.U/gm)	0.2 lb.
Delsterol (2000 A.O.A.C./gm)	0.1 lb.
Tocopherol concentrate (10mg Alpha tocopherol/gm.)	19 cc
Niacin	1.362 gm.
Menadione	0.018 gm.
Cal. pantothenate	0.454 gm.
Riboflavin	0.454 gm.
Thiamin	0.227 gm.
Pyridoxine	0.227 gm.
Folic Acid	0.0227 gm.
Biotin	0.0045 gm.
Choline Chloride	90.69 gm.
Merck APF (12 mg/lb)	51.00 gm.
Cerelose	4.39 lbs.

TABLE III

Analysis of the experimental samples of cottonseed meal (1)

	Sample A	Sample B	Sample C	Sample D	Sample E	Sample T_2*
Moisture %	6.85	7.07	7.25	6.72	5.44	
Fat %	2.04	1.90	1.36	7.58	4.80	
Thiamin Mg/lb.	3.62	3.24	3.54	2.61	1.01	
Protein %	42.56	41.53	41.88	42.56	41.88	
Sol. Protein %	26-42	32-41	30-41	26-42	11-41	
Fiber %	11.78	15.50	13.05	11.86	14.37	
Ash %	7.30	5.31	6.24	5.56	5.39	
N. F. Ext. %	29.47	28.[illegible]	30.22	25.72	28.12	
Total Gossypol %	1.03	0.83	1.21	1.04	0.78	
Free Gossypol %	0.06	0.05	0.04	0.03	0.03	

* Data not available

(1) Woodson-Tenent Laboratories, Memphis Tenn.

TABLE IV

Chemical analysis of the experimental rations (2)

Ration No.	1	2	3	4	5	6	7
Water %	9.72	9.75	9.79	9.72	9.56	9.31	8.96
Ash %	6.65	7.62	6.66	6.72	6.69	7.03	7.00
Crude Protein %	18.16	20.95	20.83	20.44	20.02	20.25	20.25
Fat %	6.45	5.54	6.51	5.82	6.70	7.03	7.10
Fiber %	1.34	1.54	1.86	2.04	2.62	2.60	2.59
N.F.E. %	57.68	54.60	54.35	55.26	54.41	53.78	54.10
Ca. %	1.26	1.27	1.31	1.29	1.19	1.23	1.42
P. %	.716	.700	.612	.682	.720	.664	.700

(2) Department of Agricultural Chemistry Research, Oklahoma A. & M. College, Stillwater, Oklahoma

TABLE V

Calculated amino acids analysis of the control and experimental diets.

	Control	Experimental	Chick requirements
Arginine	1.119	1.222	1.20
Lysine	1.041	0.864	0.90
Methionine	0.530	0.413	0.50
Cystine	0.194	0.257	0.40
Tryptophan	0.288	0.265	0.25
Glycine	2.895	2.295	1.50
Isoleucine	0.910	0.900	0.60
Leucine	1.540	1.465	1.50
Phenylalanine	1.113	1.106	0.90
Threonine	0.775	0.705	0.60
Valine	0.829	0.839	0.80
Histidine	0.449	0.464	0.30
Tyrosine	0.927	0.829	0.75

TABLE VI

The effect of soybean meal and various samples of cottonseed meal on chick growth

	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	Diet 7
Av. hatch. wt. gm.	39.2	39.5	40.0	38.3	38.2	39.3	39.8
Av. wt. at 2 wks. gm.	134	148	143	152	153	142	146
Av. wt. at 4 wks. gm.	346	345	345	358	348	333	337
Av. gain at 4 wks. gm.	307	306	305	320	309	294	297
Feed per lb. of gain	2.16	1.99	1.98	2.04	1.99	1.99	1.96
Av. gain % of control	100	99.7	99.7	104.2	100.6	95.7	96.7
Percent of mortality	6.6	6.6	2.2	0.0	0.0	0.0	0.0

EXPERIMENT NO. II.

Procedure:-- It is recognized that large amounts of cottonseed meal produced by old processing methods will inhibit growth. The maximum level of new process cottonseed meal which can be fed to chicks without retarding growth has not been established. The objective of this study is to determine the maximum level of new process cottonseed meal which can be fed without deleterious effect on growth. Cottonseed meal sample C which produced the best growth response in experiment I was used in this test. Four rations containing 12, 24, 36, and 48 percent of cottonseed meal respectively, were used. Soybean meal was used in the control ration. In those rations which contained less than 48 percent of cottonseed meal, soybean meal was used to furnish the additional protein required to standardize all the rations at the same protein level.

Crossbred (New Hampshire x Barred Plymouth Rock) straight run chicks were secured from the college poultry farm. The same general procedure used in experiment I was used in experiment II, also. Triplicate groups of twelve chicks each were fed different levels of cottonseed meal and soybean meal. The experimental period was four weeks, but due to an outbreak of a disease similar to Newcastle disease at the termination of the experiment, only the data obtained at two weeks will be discussed.

The percentage composition of the basal and experimental ration is given in Table VII. The same mineral and vitamin mixtures were used in experiment II were used in experiment I. The chemical composition of the experimental rations is shown in Table VIII.

Discussion and Results:-- The data obtained apparently contradicts the results found in the first experiment, since the soybean diet provided the best rate of growth, however, as was pointed out, the difference was not significant. The results of this experiment are given in Table IX. Lot 1 fed soybean meal as the only protein source produced a rate of growth slightly better than that of lots 2, 3, and 4. It seems likely that this difference is due to a better quality of protein in the soybean meal in this experiment. Equal growth was obtained using rations 2, 3, and 4 in which soybean meal was partially replaced by 12, 24, and 36 percent of cottonseed meal. Since ration 4 is three times higher in cottonseed meal than ration 2, it is evident that cottonseed meal containing 0.04 percent of gossypol when fed at a level of 36 percent of the ration does not retard growth to any measurable extent. Poorer results were made by lot 5 which was fed 48 percent of cottonseed meal. This indicates that the growth response was seriously inhibited by gossypol when more than 36 percent of cottonseed meal was fed. Since mortality was lower in the lots containing high amounts of cottonseed meal, it can be concluded that gossypol did not effect mortality rate in this experiment.

TABLE VII

Composition of the basal and experimental diets

Basal

Ingredient	Percentage
Cerelose	80.0
T-Cake	1.7
Methionine	.7
Vitamin Mixture	8.8
Mineral Mixture	8.8

Experimental

Ingredient	No.1	No.2	No.3	No.4	No.5
	%	%	%	%	%
Basal	52	52	52	52	52
Soybean oil meal	40	30	20	10	0
Cottonseed meal	0	12	24	36	48
Cerelose	8	6	4	2	0

TABLE VIII

Percent composition of the experimental ration (3)

Ration No.	1	2	3	4	5
Moisture	10.8	9.46	9.20	11.08	11.33
Ash	6.71	7.31	7.17	7.31	7.20
Protein	17.50	18.89	20.36	19.34	19.36
Fat	4.97	3.59	3.81	2.91	3.50
Fiber	1.45	2.57	3.25	3.13	2.46
N.F.E.	59.31	58.18	56.21	56.23	56.15
Ca.	1.42	1.33	1.33	1.37	1.31
P.	.660	.684	.840	.840	.794

(3) Department of Agr. Chem. Research, O. A. & M. College, Stillwater, Oklahoma

TABLE IX

The experimental results at 2 weeks of age.

Diets	1	2	3	4	5
Av. hatch. wt. gm.	40.36	42.5	41.1	41.9	41.2
Av. wt. at 2 wks. gm.	172.3	165.3	163.2	163.2	124.6
Av. gain at 2 wks. gm.	132.0	122.8	122.1	121.3	83.4
Av. gain % soybean diet	100	93.0	92.5	91.8	63.2
No. chicks started	36	36	36	36	36
No. chicks died	7	6	3	1	2

EXPERIMENT NO. III.

Material and Method: -- The purpose of this study is to study the ability of a prime quality commercially produced cottonseed meal to replace soybean meal in a practical type broiler ration.

Twelve groups with 35 random-selected unsexed New Hampshire chicks in each group were used in this experiment. At one day old, they were wing banded, weighed and vaccinated for Newcastle with intranasal vaccine. The experiment was started when the chicks were one-day-old and terminated at the end of the sixth week.

The chicks were brooded in a well ventilated continuous type brooder house which was divided into 12 pens. The house was equipped with a hot water brooding system. Approximately 2 square feet was allowed for each chick. The house and equipment were thoroughly cleaned and new litter was placed on the floor prior to the beginning of the experiment. Commercially treated sugar cane pulp was used for litter. No replacement or addition of litter was made during the experimental period.

The different rations were fed in triplicate. Each of the three pens fed the same ration composed one lot. The pens were numbered from 1 through 12. Besides the initial weighing, records of body weight were taken at the end of the fourth and sixth weeks. Feed was removed for a short time before each weighing was made. Records of mortality was kept throughout the test period. Fresh water and feed were supplied ad libitum except for short periods before each weighing. Feed wastage was avoided as much as possible. Feed hoppers of adequate sizes were used during the experimental period. Feed for each pen was kept in separate cans. The values for the feed consumption of each lot shown in Table XIV are averages for the three respective pens.

At the termination of the experiment the chicks were sexed. The average body weight of each lot was determined by dividing the average weight of males plus average weight of females by two. Feed utilization was calculated by dividing the total feed consumed by the total weight gain. The feed consumption of all the lots was determined at the time of each weighing. In order to facilitate a comparison of the results, the average weight gain and feed efficiency of the rations containing cottonseed meal were expressed as the percentage of that obtained from the lot fed only soybean meal as the source of vegetable protein. The gains obtained were analyzed statistically by analysis of variance.

This study compares the effect on growth and feed efficiency of cottonseed meal and soybean meal as sources of vegetable protein in a commercial broiler ration. Four experimental rations were used. Different percentages of soybean meal and cottonseed meal were added to the basal diet described in Table X. This diet was supplemented with a sufficient amount of all required vitamins and minerals needed by broilers. The levels of vitamins used were higher than that recommended by the National Council of Research. Although the calculated amount of lysine in the rations high in cottonseed meal was apparently low, no addition of that amino acid in pure form was made. The calcultated analysis of the amino acids of the experimental rations is given in Table XI. Experimental ration 1 contained 22.5 percent of soybean meal as the only plant protein supplement. In rations 2 and 3, soybean meal was reduced to 15 and 6.8 percent, respectively, while cottonseed meal was added at the levels of 7.3 and 16.7 percent. Ration 4 contained only cottonseed meal as a source of vegetable protein. The chemical analysis of the experimental rations given in Table XIII shows that all the rations contained approximately 22 percent of protein.

The soybean meal used was a solvent extracted sample obtained from the open market. Apparently it was representative of the quality of the soybean meals usually available in this section. The cottonseed meal was furnished through the courtesy of the Western Cottonoil Company, Abilene, Texas. It was a solvent extracted meal of average quality, produced for commercial purposes. Its analysis was not available at the time this paper was written. Before the rations were prepared, the cottonseed meal was thoroughly mixed in a mechanical mixer. As the cottonseed meal previously mentioned was not available at the beginning of the experiment, a sample manufactured by L. B. Lovitt and Company, Memphis, Tennessee was used during the first 10 days of the test period. The experimental rations were prepared approximately every two weeks, and mixed in a Batch mixer. Vitamins were incorporated into the basal at the time the experimental rations were prepared. Vitamin A was supplied by feeding oil containing 8000 I. U. of vitamin A per gram. Vitamin D, riboflavin, pantothenic acid, betaine supplement and vitamin B_{12} were added in crystalline form.

<u>Discussion and Results</u>: — This study was conducted between the dates of May 14, and June 25. Data on livability, growth response

and feed efficiency were obtained. Livability was excellent in all experimental lots. Only one chick died during the test period. Although lot 4 made somewhat inferior gains in weight, the general appearence of the chicks was as good as those in the three lots which showed the best growth response. At the end of the experiment, the birds looked alike. No evidence of a difference in feather color, typical of a lysine deficiency, was observed. The individual variation in body weight was apparently normal and very uniform in every lot.

The average gains in weight at four weeks of age were essentially the same for lots 2 and 3. Lot 1 made slightly better gains but the differency was not significant. Lot 4, fed only cottonseed meal as a source of vegetable protein, gained less than the other 3 lots at the fourth week of the experimental test. When analyzed statistically this difference in weight gain was found to be significant. At six weeks the gains in weight for rations 2 and 3 were the same. Ration 1, which gave the best results up to four weeks, showed a rate of growth slightly below those of rations 2 and 3 at six weeks. Gains for lot 4 were still inferior, but the gains obtained for this test period were as good as those obtained by lot 1. The different trends in the data obtained at 4 and 6 weeks can be explained on the basis of the difference in quality of the two cottonseed meal samples used.

The average feed consumption per bird at six weeks varied from 2.72 pounds in lot 4 to 2.92 pounds in lot 2. No significant difference in feed efficiency among the lots was encountered.

GENERAL DISCUSSION

A general conclusion can be drawn from the three experiments carried out on this study. Experiment I shows that cottonseed meal with a gossypol content varying from 0.03-0.05 percent was as desirable as a soybean meal for the growth of chicks when fed at a level of 15 percent of the ration. However, a slight difference in growth response was observed among these lots fed the same amounts of cottonseed meal. This difference was attributed to differences in protein quality which may have resulted from methods of processing. Experiment II shows that when cottonseed meal contains no more than 0.04 percent of free gossypol it can be used at a level up to 36 percent of the ration without apparent deleterious effect on growth. However, evidence indicates that the processing conditions under which the cottonseed meals are manufactured lower the protein quality. Experiment III shows that cottonseed meal, when combined with soybean meal is a valuable protein for broilers. Excellent growth responses were obtained when cottonseed meal replaced up to 70 percent of the soybean meal. When used as the only source of plant protein, cottonseed meal showed a slightly depressing effect on growth response and feed utilization. The results of experiment II provided evidence that gossypol did not inhibit growth when 24 percent of cottonseed meal containing 0.04 percent of gossypol was used. Unfortunately, the analyses of protein quality and gossypol content of the meal used in experiment III is not available at the present time. However, since excellent growth responses was obtained when two-thirds of soybean meal was replaced by cottonseed meal, it becomes apparent that cottonseed meal samples used provided a high quality of protein for growth. When cottonseed meal was used alone a lower rate of growth was obtained. This effect can be due either to the action of gossypol or to a deficiency in amino acids.

SUMMARY

1. The nutritional value of the protein of cottonseed meal when it is properly processed is excellent for the growth of chicks.
2. Evidence was obtained that a combination of cottonseed meal and soybean meal provides better growth than when the two proteins are fed alone.
3. Cottonseed meal can successfully replace up to two-thirds of the soybean meal in a high efficiency broiler ration.
4. Unfavorable effects on growth were observed when high percentages of cottonseed meal of 0.04 percent of free gossypol was fed. This effect is most likely due to the detrimental effect of processing on the quality of the cottonseed meal.

TABLE X

Composition of the basal diet

Ingredients	Pounds
Ground yellow corn	34.7
Ground kafir	20.0
Pulverized oats	5.0
Fish meal (60% protein)	3.0
Dried brewers yeast	2.0
Dried buttermilk	2.0
Alfalfa leaf meal (17% protein)	2.0
Meat bone scrap	3.0
Calcium carbonate	1.0
Steamed bone meal	1.0
Salt	.5
Vitamin A oil (8,000 I. U.,/gm)	.1
Delsterol (1,500 I.C.U./gm.)	.07
Betaine supplement	.02
Merck B_{12} and ant. suppl., 3 mg. B_{12}/lb. (L.L. elution assay) and 2 gm. procain penicillin per pound	.10
Riboflavin supplement (1gm/oz.)	10 gm.
Calcium pantathanate	.22 gm.
Manganese sulfate	60 gm.

TABLE XI

Calculated analyses of Amino acids of the experimental rations.

Diet No.	% 1	% 2	% 3	% 4	Require- ments
Arginine	1.28	1.31	1.37	1.41	1.0
Lysine	1.14	1.03	.94	.86	1.0
Methionine	.43	.43	.43	.43	.5
Cystine	.31	.34	.37	.40	.3
Trytophan	.23	.22	.22	.21	.25
Glycine	2.12	1.63	1.35	.96	.8
Iso Leucine	1.08	1.03	.99	.96	.6
Leucine	1.97	1.93	1.86	1.81	1.4
Phenylalanine	.99	.99	.99	.99	.95
Threonine	.85	.84	.82	.80	.7
Valine	1.15	1.12	1.09	1.06	.80
Histidine	.50	.50	.50	.50	.35
Tryosine	.80	.78	.76	.75	.75

TABLE XII

Composition of the experimental diets

Diet No.	1	2	3	4
Components	percent	percent	percent	percent
Basal	76	76	76	76
Soybean meal (44% protein)	22.5	15.7	6.8	--
Cottonseed meal (41% protein)	--	7.3	16.7	24
Ground yellow corn	1.5	1.0	.5	--

TABLE XIII

Percent composition of the experimental diets as calculated from chemical analyses of ingredients. (4)

Ration No.	1	2	3	4
Moisture %	10.35	10.78	10.82	10.99
Ash %	6.93	7.27	7.13	6.93
Protein %	23.12	23.44	22.00	22.44
Fat %	3.26	3.34	3.35	3.26
N.F.E. %	52.52	49.95	52.79	52.03
Ca. %	1.40	1.40	1.63	1.37
P. %	0.71	0.73	0.84	0.74
Fiber %	3.32	5.22	3.91	4.35

(4) Department of Agricultural Chemistry Research, Oklahoma A. & M. College, Stillwater, Oklahoma

TABLE XIV

Effect of feeding cottonseed meal and soybean meal on the weight and feed efficiency of chicks at two and six weeks of age.*

Ration No.	1	2	3	4
Av. initial weight, gm.	45	45	44	43
Av. weight 4 wks., gm.	335	328	326	297
Av. gain, 4 wks., gm.	290	283	282	254
Av. gain % s. m. diet, 4 wks. gm.	100	97	97	88
Av. weight, 6 wks., gm.	525	530	539	489
Av. gain, 6 wks., gm.	480	485	495	446
Av. gain from 4-6 wks. gm.	190	202	213	192
Av. gain, % S. meal, 6 wks.	100	101	103	93
Livability %	98	100	100	100
Av. feed con. 6 wks., lb.	2.85	2.92	2.91	2.72
Av. feed con. % S. meal, 6 wks. lbs.	100	102	102	95
Av. feed per lb. gn., 6 wk., lb.	2.47	2.49	2.45	2.52
Av. feed per lb. gn., % S. meal, 6 weeks, lb.	100	100.8	99.2	102

* Average values for the 3 pens of each lot.

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THESIS TITLE: INFLUENCE OF PROCESSINT ON THE FEEDING VALUE OF COTTONSEED MEAL

AUTHOR: Joaquim Campos

THESIS ADVISER: Professor Rollin H. Thayer

The content and form have been checked and approved by the author and thesis adviser. Changes or corrections in the thesis are not made by the Graduate School office or by any committee. The copies are sent to the bindery just as they are approved by the author and faculty adviser.

TYPIST: Mrs. Anna Cress

SUMMARY

Date: July 14, 1952

Name: Joaquim Campos

Position: Research Student

Institution: Oklahoma A. & M. College

Location: Stillwater, Okla.

Title of Study: Influence of Processing on the Feeding Value of Cottonseed Meal.

Number of Pages in Study: 51

Under Direction of What Department: Poultry Husbandry.

Statement of Problem: The biological value of cottonseed meal is dependent upon the quality of the protein and upon the amount of free gossypol, a toxic substance found in the pigment gland of cottonseed. Recent research has shown that processing conditions which reduce the free gossypol content of the meals can also damage protein quality. Commercial cottonseed meals produced by improved methods of processing have become available on the market during recent years. The purpose of this study was to determine the dietary value of these meals as compared with that of soybean meal for the growth of chicks.

Methods of Procedure: Three experiments were performed on groups of growing chicks. In the first test, six groups of chicks were fed semi-purified diets containing 15 percent of several samples of cottonseed meal which were processed under different conditions. Soybean meal replaced cottonseed meal in the control diet. In the second experiment five lots of chicks in triplicate pens were fed semi-purified rations containing 0, 12, 24, 36, and 48 percent of cottonseed meal and 40, 30, 20, 10, and 0 percent of soybean meal, respectively. The final experiment investigated the ability of cottonseed meal to replace soybean meal in a complete practical type broiler mash.

Findings and Conclusions: The results obtained permit the following conclusions:

1. The nutritional value of the protein of cottonseed meal when it is properly processed is excellent for the growth of chicks.
2. Evidence was obtained that a combination of cottonseed meal and soybean meal provides a better growth than when the two proteins are fed alone.
3. Cottonseed meal can successfully replace up to two-thirds of the soybean meal in a high efficiency broiler ration.
4. Unfavorable effects on growth were observed when high percentages of cottonseed meal of 0.04 percent of free gossypol was fed. This effect is most likely due to the detrimental effect of processing on the quality of the cottonseed meal.

Adviser's Approval Rollin H Thayer
By R B Thompson