MUNGBEANS AS A PROTEIN SOURCE
FOR GROWING-FINISHING SWINE

By

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FOR GROWING-FINISHING SWINE

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CHAPTER I

INTRODUCTION

Mungbean, a large seeded legume, is a native crop of Southern Asia. It is of considerable interest to producers in the United States because of its value as food and forage for livestock and man. Oklahoma's location, climate, soil and harvesting facilities make it the highest mungbean producer in the United States. The central section from north to south is particularly well suited for mungbean growth. Some common varieties of mungbeans grown by farmers and seedmen in Oklahoma are Berkin, Kiloga and OK12. Berkin is a jumbo, late maturing type. The pods range from 7-12 cm in length and contain 10-13 large, green glossy seeds. There are about 6,800 to 8,700 seeds per pound. Kiloga matures more uniformly, the pods are 6-11 cm, and contain about eleven shining seeds per pod. A pound contains approximately 8,700 to 11,000 seeds. The small, shiny seeds of OK12 are contained in 6-10 cm long pods. There are 10,000 to 14,000 seeds per pod and it has a good tolerance to bacteria blight.

Oklahoma producers have shown interest in this crop because it is a short season crop and can be grown immediately after wheat, utilizing much of the same equipment.

There is a much higher return for double crop wheat and mungbeans as compared to a single wheat crop. A quantity of split, broken and undersize beans become available on Oklahoma farms each year after harvest. These beans and surplus supplies of whole mungbeans can profitably be used in feeds for livestock and poultry owing to their high nutritive value. Mungbeans contain from 22 to 28% CP and have a high lysine to crude protein ratio. Vitamin A is greater than amounts found in most seeds. There is a plentiful supply of the vitamin B complex when mungbeans compose 60% of a ration. Rats can grow to maturity with the protein from this single source although growth is below normal (Heller, 1927). Protein content of mungbean cereal combinations have high nutritional potential (Chatterjee and Abrol, 1975).

The presence of antinutritive factors have been reported in mungbeans (Liener, 1976; Gutpa and Wagle, 1978). This is evidenced by the better performance of swine and poultry fed cooked or heated mungbeans when compared to raw mungbean diets (Heller, 1927; Thayer and Heller, 1949; Cannon et al., 1983; Maxwell et al., 1983). Some form of heat treatment destroys the antinutritive factor or factors, which is believed to be a proteinase inhibitor(s). Earlier studies have shown that mungbeans can constitute up to 7.5% (25% of the supplemental lysine) of the total growing ration (35-123 lb. pig weight) without adverse effect on performance (Maxwell et al., 1983). However, the maximum amount of mungbeans that can be fed to finishing swine without reducing performance has not been established. Finishing rations can contain up to 50% of the supplemental lysine from mungbeans, which is about 11.75% of total ration.

This study examines the effect of greater amounts of mungbeans on the performance of swine. Levels used in this study were 0%, 33 1/3%, and 66 2/3% of the supplemental lysine from mungbeans during the growing phase and 0%, 37 1/2%, and 75% of the supplemental lysine from mungbeans during the finishing phase.

CHAPTER II

LITERATURE REVIEW

Nutrient Composition of Mungbeans

Carbohydrates and Oil Content

Aside from the supply of protein, mungbeans make a significant contribution to the energy content of a diet. Hymowitz et al. (1975) studied the nutritional content of some 32 varieties of mungbeans. Oil and sugar content ranged from 0.57 to 0.84 g and 2.69 to 5.88 g per 100 g of seed, respectively. There was a significant ($p < .01$) negative correlation (-.58) between the oil and protein content of mungbean seeds studied. The correlation coefficient between total sugar and protein was positive but not significant. In soybeans, total sugar is negatively correlated (not significant) with protein content. Aside from sucrose, oligosaccharide of the raffinose family, stachyose and raffinose are other dominating sugars in raw mungbeans. This family contains $\alpha(1-6)$ galactose linkages which are indigestible by mammalian enzymes. Researchers have ascribed flatulence problems in legume diets to the action of intestinal anaerobic microorganisms on these bonds. Hymowitz et al. (1972) reported that certain strains of mungbeans such as PJ 374140 may be nonflatulent while other strains have the potential to be gas producers.

The fiber content of mungbeans is less than that of soybean meal (4.9/100 g of seed for mungbeans vs 5.1/100 g of seeds for soybean meal) and contains glucose, arabinose, xylose, urinic acids and galactose in high amounts (Kylen and McCready, 1975).

Proteins

Legume proteins, when used as protein supplements, make an appreciable contribution to the amino acid content of a diet. However, their protein is deficient in one or more essential amino acids. Some essential amino acids are "locked in" inhibitors which are present in the bean and are made unavailable (Liener, 1979).

Pant and Tulsiani (1969) studied the amino acid and biological value of four varieties of mungbean seeds. The main class of protein present in mungbeans is globulin (51-61%), crude protein was found to be 27-35%. Soni et al. (1975) reported the globulin content of mungbean protein was 63 to 84% with crude protein ranging from 24.3% to 27.9%. A study of the essential amino acids in the globulin albumin fractions studied by Pant and Tulsiani (1969) revealed that all 4 varieties could be considered as efficient sources of proteins if those that are incomplete in essential amino acids are supplemented. There were variations quantitatively with regard to methionine, tryptophan, and lysine.

Two varieties had only eight essential amino acids. Phaseolus Vulgaris (Pink Rajmah) and P Vulgaris (Bakla) had a low methionine content and were devoid of tryptophan. These variations were attributed to maturity, age of seed, soil type and genetic composition of the seeds. A similar observation was made by Chatterjee and Abrol (1975) who revealed that methionine and tryptophan are present in low amounts in some varieties of mungbeans. These authors also studied the nutritional potential of cereal-mungbean combinations with the view of balancing the amino acids which are inadequate in mungbeans. A whole wheat meal and mungbean (Var. "Pusa Baisakhi") mixture in the proportion of 90:10 resulted in an increase in the chemical score of the protein in the mixture over that of either of the components alone. Similar trends were observed with rice-mungbean and maize-mungbean combinations in a ratio of 80:20. Threonine was found to be the most limiting amino acid in these combinations. It was concluded from this study that mungbeans and cereal proteins complement each other and that the nutritional value of a cereal-mungbean combination would be limited by the content of methionine and threonine in the mixture.

Research conducted by Sekhon et al. (1979) with nineteen varieties of mungbeans indicated that the methionine content in all strains was very low, 0.51-1.00 g/100 g of protein. This figure is close to that observed by Bandemer and Evans (1963), who reported the methionine content of mungbeans to be 1.1 g/100 g protein. Lysine, a limiting amino acid in swine rations, was found to be very high in mungbeans (5.51-7.58 g per 100 g protein). The low methionine content contributed to the low chemical score of the strains studied. The authors studied the correlation coefficients among protein and amino acids of mungbeans. Protein content was negatively correlated with lysine and threonine. However, methionine content had a significant positive correlation with lysine and threonine. It was concluded that any attempt to increase these amino acids in mungbean protein genetically will have to be made at the expense of protein content. Hang et al. (1980) also analyzed the amino acid composition of high protein fractions prepared from mungbeans, peabeans and red kidney beans. Their studies demonstrated that high protein fractions containing 55% protein can be prepared from mungbeans, and because of the low threonine and sulfur containing amino acid content, mungbeans must be combined with other protein sources for optimum nutrition. They also suggested that the high protein bean fractions can be used in the same manner as soybean protein. Del Rosario et al. (1980), who worked on 17 mungbean varieties, concluded that cystine-methionine, isoleucine, and threonine constitute the first, second, and third limiting amino acid of mungbeans, relative to the amino acid pattern of egg protein, and that the high lysine content will make mungbean a useful complement to cereal grain proteins.

Vitamins and Minerals

Mungbeans contain greater amounts of vitamin A than that found in most seeds, and have an abundant supply of the vitamin B complex when they make up to 60% of a ration (Heller, 1927). Prudente and Mabesa (1981) reported that the vitamin content of mungbeans increased significantly after sprouting and cooking. This is consistent with the findings of Kylen and McCready (1975) who observed an increase in the niacin and riboflavin content of mungbean seeds after sprouting. Mungbeans have high levels of potassium (1.265 to 1.396%), and are good sources of phosphorus (0.348 to 0.4496%) and iron (53 to 84 ppm). They are, however, a poor source of calcium and sodium (Del Rosario et al., 1980).

Feeding Mungbeans to Nonruminants

Rats

Pant and Tulsiani (1969) fed isolated globulin fractions of four varieties of mungbeans to 4-5 week old albino rats for 5 weeks. Growth was obtained with diets containing two of the varieties. Body weight of experimental animals fed isolated protein fractions of the other two varieties gradually decreased under identical conditions. Amino acid analysis of the two varieties which failed to promote growth showed a total absence of tryptophan and a low level of methionine. In spite of the adequate amino acid content of the varieties which promoted growth there were significant differences in weight gain. The diet containing one variety promoted growth equivalent to that obtained in rats fed the casein control diet while the other variety produced lower gains. It was suggested that the availability of amino acid was not adequate in one variety for proper growth. The inadequacy of amino acid in mungbean protein has been reported by many workers including Heller (1927), Thompson and Hillier (1942), and Chatterjee and Abrol (1975).

Poultry

As early as 1930, the Bureau of Animal Industry in the Philippines and the surrounding islands recommended the use of mungbeans in rations for baby chicks, growing chickens, and laying hens. Tuason and Fronda (1924), of the Philippines, tested the palatability of some ground feeds of which mungbeans rated third, and shrimp meal and fish meal rated first and second, respectively. Mungbeans were made more palatable by the addition of corn meal. Adan (1935) studied the influence of mungbeans on the rate of growth and mortality rate of chicks using diets containing mungbean at 0, 10, and 20% of the diet. The 20% diet had no animal protein while the 0 and 10% mungbean diets contained 10 and 20% shrimp meal, respectively. Weight of chicks on the 20% mungbean diet was far below the normal weight of growing chicks. Feed intake was low and percentage mortality was high in birds fed this diet compared to those fed either the shrimp meal or mixed supplement diets. Mungbeans were also found to be inefficient in stimulating the growth of feathers.

Thayer and Heller (1949) studied the utilization of mungbeans in poultry feeds and made the following recommendations:

1. Satisfactory growth can be obtained when mungbeans are supplemented with animal protein and phosphorus.

2. Ground mungbeans can make up as much as 30% of poultry mash with satisfactory results.

3. About 1 1/2 pounds of mungbeans are required to replace 1 pound of cottonseed meal or soybean meal, since mungbeans contain less protein. Their study included the effect of mungbeans on egg quality, egg production, and hatchability. No significant effect on egg quality production or hatchability was observed when mungbeans formed 30% of layer mashes. In another trial, it was observed that mungbeans heated at 15 pounds of pressure for 30 minutes were nutritionally superior to raw beans.

The nutritionally beneficial effect of heat treatment of mungbeans was observed by Cannon et al. (1983). They conducted a chick growth assay in which mungbeans were used raw or autoclaved at 150 °F for 45 minutes. Mungbeans replaced soybean meal on an equal nitrogen basis at levels of 0. 20, 40, 60, 80, and 100%. Chicks fed raw beans tended toward lower weight gains and increased intake at higher levels of mungbean replacement. It was suggested that this was due to an antinutritive factor, probably a trypsin inhibitor in raw mungbeans. However, the nonheat treated mungbean, when comprising up to 40% of the nitrogen, did not significantly affect weight gain or feed intake.

Swine

Thompson and Hillier (1942) conducted swine feeding trials using crossbred and purebred pigs to determine (1) the value of ground mungbeans as protein supplement for swine; (2) whether ground mungbeans alone will make satisfactory protein supplement to corn; and (3) whether a ration containing 30% of ground mungbeans will produce soft pork. The control diet consisted of corn (85%), meat scraps (7.50%), cottonseed meal (3.75%), alfalfa leaf meal (3.75%) and a mineral mixture. In the first experimental diet ground mungbeans replaced cottonseed meal and in the second diet ground mungbeans replaced both cottonseed meal and meat scraps. It became evident that mungbeans are a good substitute for 43% cottonseed meal but not a satisfactory substitute for both animal protein and cottonseed meal. Substitution of an equal amount of protein from mungbeans for protein in the meat scraps and cottonseed meal resulted in a reduction of average daily gain of 0.31 pounds, a decrease in feed efficiency of 47.1% and an increase in feed cost per gain of $0.80. There was no significant difference in firmness and appearance of the carcasses of swine fed the three rations.

Another research trial was conducted by Maxwell et al. (1983) to determine the optimum level of mungbeans which can replace soybean meal without affecting performance. The three treatments were a corn soybean meal control diet, the control diet with 25% of the supplemental lysine supplied by mungbeans and the control diet with 50% of the supplemental lysine supplied by mungbeans. In the growing phase (35-123 pounds), mungbeans added to the diet in increments of 25% of supplemental lysine resulted in a 4% decrease in average daily gain ($p < .05$). Feed efficiency was significantly reduced when mungbeans replaced 50% of the supplemental lysine. During the finishing phase (123-233 pounds), average daily gain, feed efficiency and feed intake were not affected by the addition of mungbeans (up to 50% of the total supplemental lysine in the diet). The authors concluded that the decrease in performance during the growing period at both levels of mungbean replacement is an indication that some inhibitor(s) may interfere with the utilization of proteins, and that older pigs can handle larger amounts of inhibitors. A 25% supplemental lysine replacement from mungbeans (7 1/2% of total ration as mungbean) was established as the upper limit for growing pigs. The upper limit for growing-finishing swine was not established for this trial. Backfat thickness was not affected by dietary treatments.

Antinutritive Factors in Legumes and Their Role in Nonruminant Nutrition

Osborne and Mendel (1917) first demonstrated the nutritionally beneficial effect of heat-treatment on raw soybeans. This discovery generated a great deal of interest among scientists to identify the factor(s) responsible for the growth depression caused by certain plant proteins. Much of the work done in this area has been with soybean protein. The discovery of trypsin inhibitors in this bean by Bowman (1944) and Kunitz (1947), offered some explanation for the improvement in its nutritional quality after heating. Since that time, numerous studies have been conducted to investigate the involvement of trypsin inhibitors and other toxic factors on the nutritional value of plant proteins. The main antinutritive factors in legumes, the main source of plant proteins, are flatus factors (Hymowitz et al., 1972; Gupta and Wagle, 1978), phytohemagglutinins or lectins (Liener, 1976; Meyer and Froseth, 1983) and trypsin inhibitors (Lyman and Lepkovsky, 1957; Pusztai, 1967).

The presence of flatulence factors in legumes has been discussed earlier in this review. Gupta and Wagle (1978) reported that the flatulence factors of two varieties of mungbeans, Phaseolus aureus, Phaseolus mungo, and their cross, Phaseolus mungoreous, range from 26.9 to 31.0 mg/g of flour. Researchers suggest a possibility of reducing this undesirable legume trait through crossbreeding and genetic selection. The poor digestibility of legume seeds has been solely ascribed to the presence of trypsin inhibitors. Their chemistry and role in animal nutrition have been extensively studied from the past years to the present time. Different legume seeds contain one or more inhibitors which are homologous. Their molecular weights range from 3,000 to 25,000. The abundance of S-S bonds account for the considerable resistance to proteolytic digestion and the fact that some inhibitors are not destroyed by heat. The most extensively studied proteinase inhibitors are those obtained from soybeans. Soybeans contain two main classes of trypsin inhibitors, the Kunitz type inhibitor with high molecular weight and low cystine content, and the Bowman-Birk type with low molecular weight and high cystine content. A single legume plant species contains several Bowman-Birk type inhibitors with different specificities and properties known as iso inhibitors (Odani et al., 1979). Borchers et al. (1947) first suggested the presence of trypsin inhibitors in the seeds of Phaseolus aureas (a variety of mungbean). A heat stable inhibitor with a molecular weight of 18,000 was later isolated from mungbean. It was found to be highly active and noncompetitive. One microgram inhibited 1 μg of trypsin. Pepsin and chymotrypsin were not inhibited by mungbean (Paureus) inhibitor (Pusztai, 1967). Other extensive studies by Chou Chi et al., cited by Pusztai (1967), revealed that there are two types of inhibitors in Phaseolus aureas, types A and B. A was derived from B. These inhibitors contain S-S bridges and their reduction results in activity against trypsin. Activity is partly recovered by oxidation. Unlike other trypsin inhibitors in legumes, Type A Phaseolus inhibitor was found to be divalent with regard to its trypsin binding capacity.

The significance of proteinase inhibitors in legume seeds and other plant proteins has been questioned. It has been suggested that the inhibitors have evolved as a defense mechanism against insects. Seeds such as soybeans and wheat grains contain inhibitors of laval gut proteases of the insects Tribolium and Tenebrio, which feed on grain. It was reported that the wounding of leaves of some plants by insects induces a rapid accumulation of chymotrypsin inhibitor (Green and Ryan, 1972). The inhibitor content of seeds increase with maturation.

The role of trypsin inhibitors in animal nutrition has been investigated by many workers using mainly soybean trypsin inhibitors, inhibitors form other legumes, or partially purified preparations of the inhibitors (Lyman and Lepkovsky, 1957; Yen et al., 1977, 1974; Barnes and Kwong, 1965; and Kakade et al., 1973). The findings indicate that feeding raw legume seeds or trypsin inhibitor extract causes reduced feed intake and retarded growth in nonruminants. Aside from causing pancreatic hypertrophy and hyperplasia in rats and chicks, trypsin inhibitors may have some effect on fat absorption in the chick (Nesheim et al., 1962). These effects ascribed to the presence of trypsin inhibitors can be influenced by age, sex and species of the animal being fed, the quality and type of protein supplementation, and the type and activity of trypsin inhibitor present in the bean.

Researchers have tried to explain the mechanism behind the growth depression and other antinutritional effects observed when feeding legume proteins to livestock. One school of thought is that trypsin inhibitors present in the beans cause proteolytic blockage, which might decrease the availability of certain amino acids necessary for growth. Direct evidence of intestinal proteolytic inhibition was demonstrated by Nitsan and Alumot (1964) in chicks and by Yen et al. (1977) in swine. These authors found a high percentage of nitrogen in solids in both halves of the small intestine in growing swine and chicks fed raw soybean. Nitsan and Alumot (1964) reported that overcoming the inhibition depends on the age of chicks. Young chicks of one and two weeks of age suffer longer proteolytic inhibition than older chicks. This observation was explained by the facts that (1) overcoming the inhibition is dependent upon the ability of the pancreas to grow rapidly and secrete enzymes in the presence of the inhibitor; and (2) the ratio between the maximal amount of enzymes that can be secreted at a given age and the amount of inhibitor consumed with feed. The process of pancreatic adaptation, any change in an organism's structure or function that allows it to better cope with conditions in the environment, has been described by Snook (1972). Rats fed trypsin inhibitor diets produce and secrete more pancreatic protease, presumably to overcome the inhibition during digestion. Since proteolytic inhibition is overcome by secretion of more enzymes, it was proposed that growth inhibition by raw legume diets is caused by endogenous loss of protein via excessive pancreatic secretion.

Lyman and Lepkovsky (1957), cited by Snook (1972), observed that pancreatic enzymes were increased in intestinal contents and depleted more rapidly from the pancreas when rats were fed a meal of raw rather than heated soybean meal. An addition of 0.87% soybean trypsin inhibitor depressed amylase and significantly increased chymotrypsinogen and trypsinogen in the pancreas. It was concluded that the biosynthesis of chymotrypsinogen and trypsinogen increased in rats fed soybean trypsin inhibitor (SBTI). A similar stimulating effect of raw soybean or SBTI diets on the pancreas has been observed in chicks and pigs, Yen et al. (1977). However,it is well documented that excessive pancreatic secretion leads to pancreatic hypertrophy in chicks and rats (Nitsan and Alumot, 1964; Myer et al., 1982; Lyman and Lepkovsky, 1957) while there is no such observation in swine (Yen et al., 1977; Myer and Froseth, 1983). Patten et al. (1971) also reported that although synthesis of trypsinogen and chymotrypsinogen was temporarily impaired in dogs fed 15 or 30% raw soybean meal diet, the cellular structure or weight of the pancreas was not altered. Liener (1979) reported an interesting relationship between the size of the pancreas of various species of animals and their sensitivity to pancreatic hypertrophy induced by raw soybeans or the inhibitor. Animals whose pancreas weight exceeds 0.3% of their body weight become hypertrophic when fed raw beans while those whose weight falls below this value are insensitive to the inhibitor effect from the raw beans.

Another suggested cause of the effect of trypsin inhibitors in growth reduction is their influence over the metabolic conversion of methionine to cystine and over the use of cystine for synthesis of proteins. Carroll et al. (1953) observed that rats fed raw soybean meal had abnormally high concentrations of protein bound cystine in the intestine. When rats were fed a diet containing heated soybean meal, given a dose of crystalline soybean trypsin inhibitor and followed in two hours by a dose of labeled methionine through stomach tubes, there was an increase in labeled carbon dioxide ($^{14}CO_2$) expired to the level which is usually obtained with raw bean meal diets (Kwong and Barnes, 1963). The authors interpreted this as the result of an increased conversion of methionine to cystine caused by the trypsin inhibitor. Further investigation by Barnes and Kwong (1965), using labeled methionine, showed high levels of labeled cystine in the pancreas. The greater part of the labeled cystine was incorporated into pancreatic protein which is lost by secretion into the gut. This metabolic effect, according to the authors, accounted, at least in part, to the growth depression observed when unheated soybeans are fed. Supplementation of raw soybean diets with methionine can partially correct the growth depression in rats and chicks (Booth et al., 1960; Yen et al., 1971, 1973). No such correction is observed in swine when diets are supplemented with methionine (Jimenez et al., 1963; Yen et al., 1974).

A report by Liener (1976) revealed that only 40% of the growth depressing activity and a similar fraction of the pancreatic hypertrophy effect of raw soybeans can be associated with the action of trypsin inhibitors. This became evident when Kakade et al. (1973) fed (1) an unheated soy protein from which the inhibitor had been selectively removed by affinity chromatography; (2) the original soy protein extract from which the inhibitor had not been removed; and (3) and heat-treated soy protein extracts to 21 day-old weanling rats. The extracts provided 10% protein in the experimental diets. The removal of the inhibitor increased the PER from 1.4 to 1.9. However, heat treatment resulted in a further increase of PER to 2.7. The sizes of the pancreas were also measured for the various treatments. There was a greater reduction in size of the pancreas by the heated soy protein compared to the protein from which the inhibitor had been removed. It became evident by calculation from the data obtained that 40% of the increase in PER and the decrease in pancreatic size was due to the presence of trypsin inhibitor in the raw soybean seed. Also included in this study was an invitro digestibility trial using trypsin and the protein extract from which the inhibitor had been removed. By comparing the results with the original protein extract before and after heating, it became obvious that the absence of the inhibitor enhances the susceptibility of protein to proteolytic attack by trypsin and heating further increases its digestibility. In another trial by Yen et al. (1971), a raw soybean diet resulted in both a slightly greater trypsin inhibition and a significantly greater chymotrypsin inhibiting effect than soybean trypsin extract did, which had the same calculated soybean trypsin inhibitor potency as the raw soybean diet. They attributed the inhibiting effects of the raw bean to be partly due to soybean trypsin inhibitor and other factors.

The presence of phytohemagglutinins or lectins have been reported in some legumes. Studies on the effect of removing lectins on growth promoting activity of raw soybeans revealed that lectins have little or no effect on the nutritional quality of soybeans (Honaver et al., 1962). Phaseolus aureas, a variety of mungbean, has zero hemagglutinating activity. However, it has been shown that feeding lectins from other beans can result in decreased performance. Feeding of lectins isolated from two varieties of Phaseolus vulgaris at various levels to rats on a basal ration containing 10% casein resulted in growth depression at 0.5% level (Liener, 1976). In another experiment by

Meyer and Froseth (1983), feeding a 15% raw Phaseolus vulgaris diet reduced the rate and efficiency of gain ($p < .01$) in young pigs. Jaffe' (1960) postulated that lectins combine with the cells lining the intestinal wall, causing a nonspecific interference with the absorption of nutrients.

Heat processing, such as autoclaving, decreases the detrimental effect of the many antinutritional factors in raw beans (Pusztai, 1967; Liener, 1976; and Cannon et al., 1983). On a large scale, autoclaving is not a practical process. Extrusion, a more practical method of heat processing, has been described by Harper (1978). Waldroup et al. (1976) suggested that extrusion may disrupt the cell walls and expose the cell contents of the seed for more efficient digestion.

CHAPTER III

MATERIALS AND METHODS

Experimental Methods

Four hundred and eighty-two pigs were used in this study conducted at the Southwestern Livestock and Forage Research Station, El Reno, Oklahoma, in the Fall of 1984. The pigs had been selected for three generations for rapid or slow average daily gain. Barrows and gilts from each growth line were randomly assigned to three dietary treatments (Table I) at eight weeks of age, and given one week to acclimate on a control diet before starting the trial. Treatments consisted of (1) a control corn-soybean meal diet; (2) the control diet with one-third of the supplemental lysine supplied by mungbeans (10.15% mungbeans at the expense of soybeans); and (3) the control diet with two-thirds of the supplemental lysine supplied by mungbeans (20.65% mungbeans at the expense of soybeans) for the growing period (38-120 lbs.). Diets for the finishing period (Table II) consisted of (1) control corn-soybean meal finishing ration; (2) the control diet with 37.5% of the supplemental lysine supplied by mungbeans at the expense of soybean meal (8.59% mungbeans); and (3) the control diet with 75% of the supplemental lysine supplied by mungbeans

TABLE I

COMPOSITION OF EXPERIMENTAL RATION

	Growing		
Ingredients	Control	MB 33 1/3[a]	MB 66 2/3[b]
Corn, yellow	76.87	73.28	69.05
Soybean meal	19.53	12.89	6.59
Mungbeans	----	10.15	20.65
Dicalcium phosphate	1.64	1.74	1.82
Calcium carbonate	0.82	0.80	0.75
Salt	0.40	0.40	0.40
Vitamin trace-mineral mix[c]	0.25	0.25	0.25
Tylan 10	0.50	0.50	0.50
Calculated composition[d]			
Lysine	0.75	0.75	0.75
Calcium	0.75	0.75	0.75
Phosphorus	0.65	0.65	0.65

[a] One-third of the supplemental lysine was supplied by mungbeans.
[b] Two-thirds of the supplemental lysine was supplied by mungbeans.
[c] Supplied 4,000,000 IU vitamin A, 3,000,000 IU vitamin D, 4 g riboflavin, 20 g panthothemin acid, 30 g niacin, 800 g choline chloride, 15 mg vitamin B^{12}, 10,000 IU vitamin E, 2 g menadione, 200 mg iodine, 90 g iron, 20 g manganese, 10 g copper, 90 g zinc and 100 mg selenium per ton of feed.
[d] Based upon analyzed value for the lysine level in mungbeans.

TABLE II

COMPOSITION OF EXPERIMENTAL RATION

Ingredients	Finishing Control	MB 37 1/2[a]	MB 75[b]
Corn, yellow	82.32	79.21	75.22
Soybean meal	14.61	9.09	3.75
Mungbeans	----	8.59	17.88
Dicalcium phosphate	1.50	1.58	1.65
Calcium carbonate	0.82	0.78	0.75
Salt	0.40	0.40	0.40
Vitamin trace-mineral mix[c]	0.25	0.25	0.25
Tylan 10	0.10	0.10	0.10
Calculated Composition[d]			
Lysine	0.62	0.62	0.62
Calcium	0.70	0.70	0.70
Phosphorus	0.60	0.60	0.60

[a]Thirty-seven and one-half percent of the supplemental lysine was supplied by mungbeans.
[b]Seventy-five percent of the supplemental lysine was supplied by mungbeans.
[c]Supplied 4,000,000 IU vitamin A, 3,000,000 IU vitamin D, 4 g riboflavin, 20 g panthothemin acid, 30 g niacin, 800 g choline chloride, 15 mg vitamin B12, 10,000 IU vitamin E, 2 g menadione, 200 mg iodine, 90 g iron, 20 g manganese, 10 g copper, 90 g zinc and 100 mg selenium per ton of feed.
[d]Based upon analyzed value for the lysine level in mungbeans.

(17.88% mungbeans). The diets for both growth periods were balanced for lysine, calcium and phosphorus. Lysine and calcium levels were constant at .75% and phosphorus was .65% of the diet for the growing phase, while lysine, phosphorus and calcium were at .62%, .70% and .60%, respectively, for the finishing phase (120-220 lbs.). Pigs were housed in two barns (A and B). Barn A consisted of 22 pens while B had 14 pens. Each pen contained 14-18 pigs. Pens were equipped with self feeders and waterers and had a solid concrete floor.

Data Collection and Statistical Analysis

Animals were weighed at the beginning and end of the growing and finishing periods. Feed intake was determined for the two phases of production. Backfat measurements were taken with an Ithaco Scanoprobe at the first rib, last rib and last lumbar areas when the pigs were removed from the test at approximately 220 lbs. Average daily gain and backfat thickness were analyzed on an individual pig basis while feed efficiency and feed intake were analyzed on a pen basis. The main effects (barn, sex, line, ration) and two factor interactions (sex x line, line x ration, sex x ration) were determined. Sex and interactions with sex were not analyzed for intake or feed efficiency since each pen was mixed. Means reported are least square means. Significant differences between means were determined by least significant difference.

CHAPTER IV

RESULTS AND DISCUSSION

The effect of levels of mungbeans in the experimental diets on the performance of swine during the growing period are summarized in Table III. Data from the two growth lines are presented separately since there was a line by treatment interaction ($p < .001$). Replacement of one-third and two-thirds of the supplemental lysine from soybean meal with mungbeans resulted in a 5.4 and 14% decrease in average daily gain ($p < .01$), respectively, when compared to the control for the fast growth line pigs (Line 1). In the slow growth line pigs (Line 2) the same levels of mungbean substitution resulted in a 9.4 and 8.7% decrease in average daily gain ($p < .01$) when compared to the control. There was a significant reduction in average daily gain between the one-third and two-thirds levels of mungbean replacement in the fast growth line pigs but not the slow growth line. Apparently, the effect of the mungbean diet on gain was much more evident in the fast growth line at the higher level of mungbeans (66 2/3% supplementation). This difference in response between lines resulted in a line by treatment interaction ($p < .001$). Thompson and Hillier (1942) also observed a decrease in average daily gain of 0.31 pounds

TABLE III

THE EFFECT OF MUNGBEANS ON AVERAGE DAILY GAIN (ADG), FEED INTAKE (ADF) AND FEED EFFICIENCY FOR THE GROWING PHASE OF PRODUCTION[a,b]

Line 1

Item	Control	Treatment MB 33 1/3	Treatment MB 66 2/3
No. Pigs/Treatment	85	177	86
Initial Weight, lb.	37.82±.00	37.82±.00	37.82±.00
Final Weight, lb.	115.22±2.03	116.98±1.84	110.68±1.95
ADG, lb	1.66±.02[c]	1.57±.02[d]	1.42±.02[e]
ADF, lb.	4.31±.20	4.26±.16	4.11±.20
Lbs. Feed/lbs. Gain	2.62±.13	2.73±.11	2.92±.13

Line 2

Item	Control	Treatment MB 33 1/3	Treatment MB 66 2/3
No. Pigs/Treatment	51	50	93
Initial Weight, lb.	37.82±.00	37.82±.00	37.82±.00
Final Weight, lb.	126.18±2.68	121.17±2.91	117.65±1.80
ADG, lb.	1.49±.03[c]	1.35±.03[d]	1.36±.02[d]
ADF, lb.	3.62±.26	3.56±.27	3.58±.19
Lbs. Feed/lbs. Gain	2.52±.16	2.67±.17	2.65±.12

[a]Data presented are least square means. [b]Barrows had greater ADG than gilts. Fast growing pigs had higher ADG and ADF than slow growing lines. There was a line by ration interaction with regard to ADG ($p < .001$). [cde]Means in the same row with different superscripts are significantly different ($p < .01$).

when they substituted an equal amount of protein from mungbeans for protein in meat scrap and cottonseed meal. In a previous trial by Maxwell et al. (1983), there was a 4% decrease in gain as mungbean replaced 25 and 50% of the supplemental lysine from soybean in swine diets. The decrease in performance with the feeding of mungbeans or plant proteins in general has been ascribed to the presence of trypsin inhibitors in the beans which impair protein utilization (Cannon et al, 1983; Maxwell et al, 1983). The difference in response of the two lines of pigs at increasing levels of supplemental lysine replacement with mungbeans may be explained by the fact that pigs in the fast growth line ate more feed than pigs in the slow growth line ($p < .01$); thus fast growth pigs were exposed to larger amounts of inhibitors.

Average daily feed intake and feed efficiency were not significantly different within each growth line. However, there was a trend toward reduced feed efficiency with mungbean replacement of supplemental lysine from soybeans, when compared to the control. It is evident that 33 1/3% replacement exceeded the level which can be tolerated by growing swine. In an earlier trial (Maxwell et al., 1983), 25% level of the supplemental lysine replacement (7.5% mungbeans in diet) did not cause any decrease in feed efficiency in the growing phase of production.

The effect of 8.6 and 17.9% mungbeans (37.5 and 75% supplemental lysine) replacement in the diet of finishing

TABLE IV

THE EFFECT OF MUNGBEANS ON AVERAGE DAILY GAIN (ADG), FEED INTAKE (ADF) AND FEED EFFICIENCY FOR THE FINISHING PHASE OF PRODUCTION.[a,b]

Item	Control	Treatment MB 37 1/2	MB 75 q
No. Pigs/Treatment	136	167	179
Initial Weight, lb.	120.70±1.74	119.08±1.86	114.17±1.30
Final Weight, lb.	223.14±1.34	224.40±1.44	220.03±1.00
ADG, lb.	1.94±.03[c]	1.83±.03[d]	1.80±.02[d]
ADF, lb.[e]	6.21±.28	6.10±.28	5.99±.23
Lbs. Feed/lb. Gain	3.34±.13	3.50±.13	3.45±.11

[a]Data presented are least square means. [b]Barrows and fast growing lines had significantly greater ADG ($p < .01$) than gilts and slow growing lines. [cd]Means in the same row with different superscripts are significantly different ($p < .01$). [e]Fast growing lines had significantly greater ADF than slow growing lines ($p < .01$).

swine on performance is shown in Table IV. Data from the two growth lines were combined since there was no interaction among any of the variables studied. Replacing either 37.5or 75% of the supplemental lysine from soybeans with mungbeans resulted in a reduction ($p < .01$) in average daily gain of 5.7 and 7.2% when compared to swine fed the control diet. Again, there was a trend toward lower feed intake and feed efficiency with increased amounts of mungbeans in the diets. This result was inconsistent with an earlier trial which indicated that finishing swine can utilize up to 50% lysine without adverse effects on performance (Maxwell et al., 1983). Since the inhibitor content of the mungbeans used in both trials were not determined, it might be that antitrypsin activity in the experimental diets of the first trial was lower than that of this trial. Research with trypsin inhibitors indicate that their effect on protein nutrition depends on the type and activity of the inhibitor present in the seed.

Performance for the overall growing-finishing period is shown in Table V. Similar to the trend in the separate growing periods, there was a decrease in average daily gain of 5.6 and 9.1%, respectively, ($p < .01$) at 33 1/3 / 37 1/2 and 66 2/3 / 75% of the supplemental lysine replacement with mungbeans. Feed intake and feed efficiency decreased with mungbean supplementation although this was not significant.

Another important trait studied was the influence of mungbean substitution on backfat thickness. Similar to the

TABLE V

THE EFFECT OF MUNGBEANS ON AVERAGE DAILY GAIN (ADG), FEED INTAKE (ADF), FEED EFFICIENCY AND AVERAGE BACKFAT FOR THE ENTIRE GROWING-FINISHING PHASE OF PRODUCTION[a,b]

Item	Control	Treatment MB 33 1/3 α 37 1/2	MB 66 2/3 α 75
No. Pigs/Treatment	136	167	179
Initial Weight, lb.	37.82±.00	32.82±.00	37.82±.00
Final Weight, lb.	223.14±1.34	224.36±1.44	220.03±1.00
ADG, lb	1.76±.02[c]	1.66±.02[d]	1.60±.01[d]
ADF, lb[e]	5.23±.23	5.16±.23	5.07±.19
Lbs. Feed/lb. Gain	3.06±.12	3.21±.12	3.22±.10
Avg. Backfat, in.	1.17±.01	1.19±.02	1.18±.01

[a]Data presented are least square means. [b]Barrows and fast growing lines had significantly greater ADG and backfat thickness than gilts and slow growing lines ($p < .01$). [cd]Means in the same row with different superscripts are significantly different. [e]Fast growing lines had significantly greater ADG than slow growing lines ($p < .01$)

observation made by Maxwell et al. (1983), backfat thickness was not affected by dietary treatment since mungbean substitution did not produce any major changes in the energy content of experimental diets compared to the control. The data were also analyzed by sex and line. Barrows and fast growth line pigs had significantly greater average daily gain and backfat thickness than gilts and slow growth line pigs ($p < .01$) in the growing and finishing phases. A greater average daily feed intake was observed in the fast growth line when compared to the slow growth line in both growing periods.

Yen et al. (1977) also investigated the effect of soybean trypsin inhibitor on the performance of swine. He attributed the observed growth reduction to the inhibition of intestinal proteolysis caused by the soybean trypsin inhibitor and other factors present in soybeans. Since mungbeans also contain trypsin inhibiting factors (Puzztai, 1967), the poor performance might be due to inhibitor(s) interfering with proteolysis. It has also been suggested that supplementation of legume diets with methionine can partially correct the growth depression observed in rats and chicks (Booth et al., 1960; Yen et al., 1971), although a correction with methionine supplementation was not observed in pigs. Yen et al. (1974) suggested that higher levels of methionine supplementation might be beneficial in pig diets.

Heat processing improves the value of plant proteins in animal diets. There was an improvement in feed efficiency in chicks fed mungbeans autoclaved at 120° F for 45 minutes compared to those fed raw mungbeans (Cannon et al., 1983). A similar observation was made by Thayer and Heller (1949) with mungbeans heated at 15 pounds of pressure for 30 minutes. The mungbeans used in this trial can be heat processed first before inclusion in the experimental diets. A more practical and inexpensive method of heat processing has been described by Harper (1978). The cost aspects of such an undertaking should be considered first before the application.

CHAPTER V

Summary

Initial studies to determine the value of mungbeans as a protein source for growing finishing swine revealed that up to 25% of the supplemental lysine from soybean meal can be replaced with mungbeans (7.5% of mungbeans in diet) in the diet of growing swine and up to 11.75% (50% of the supplemental lysine replacement) for the finishing phase of production without adverse effects on performance. This study was conducted to determine whether greater amounts, above 25%, of supplemental lysine can be replaced with mungbean for the growing phase and whether finishing swine can be fed diets with more than 11.75% mungbeans. Four hundred and eighty-two pigs (averaging 38 lbs.) from two growth lines (selected for rapid and slow growth) were randomly allotted to three dietary treatments. The experimental diet for the growing phase consisted of a control corn-soybean meal diet or the control diet with either one-third or two-thirds of the supplemental lysine from soybean meal replaced with mungbeans. During the finishing phase, 37.5 and 75% of the supplemental lysine was replaced with mungbeans. Replacement of soybean meal with mungbeans at all levels reduced average daily gain in both phases of production

(p < .01). Similarly, there was a nonsignificant decrease in average daily feed intake and feed efficiency in pigs fed mungbean diets when compared to those fed the control diet. Backfat thickness was not affected by dietary treatment. Except for a line by treatment interaction in average daily gain, both lines of pigs responded similarly to dietary treatment. The results of this study suggest that the maximum level of mungbean which can be included in swine diets is between 25 and 33 1/3% of the supplemental lysine replacement for the growing pig and less than 37 1/2% of the lysine replacement in the finishing phase of production.

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