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Evaluation of the Impact of Meat and Bone Meal Nutritional Variability on Broiler Performance

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Evaluation of the Impact of Meat and Bone Meal Nutritional Variability on Broiler Performance

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Abstract

The objective of this trial was to determine if varying the nutritional composition of meat and bone meal (MBM) would impact broiler performance and yield compared to diets which provide a consistent quality of MBM. Twelve hundred day-old male broilers from the Cobb 500 female line were randomly allocated to 48 pens (25 chicks/pen; 22 square feet) and grown to 49 days of age. Starter, grower, and withdrawal diets were formulated to contain MBM at 10, 7.5 and 5% respectively using the Cobb nutritional standards. Four treatments provided were: 1) H.J. Baker proprietary blend, ProPlus 57 fed continuously; 2) MBM 50 formulated diet fed continuously; 3) MBM 50 specs used for formulation but starting day 14, the MBM was rotated between MBM 45, 50 and 55 with no formulation adjustments to compensate for any nutritional differences: 4) MBM 50 specs used in formulation but replaced with MBM 45 in the actual diet. Each pen was provided feed and water *ad libitum* throughout the grow-out period. Birds were weighed on days 0, 14, 28, and 49 and feed consumption data was also collected for each period. Birds were processed on day 50 and live weight, pre-chill, post chill, pectoralis major and minor, wings, leg quarters, and skeletal weights were collected from individual birds. Data was analyzed using PROC GLM with dietary treatment serving as the main effect in SAS. Treatment 3 and 4 weights were lower (P=.0142) at day 49. There were no significant differences at days 0, 14, or 28. There was a significant difference in feed conversion at day 14 (P=.0397) with treatment 4 being significantly worse than treatment 2 and 3. Also at day 28 (P=0.0003), with treatment 4 being significantly higher than all other treatments. Processing results showed no significant differences in yield except for the skeletal with treatment 1 being the heaviest (P=.0352). These results suggest that while marginal variation in MBM does not influence early performance, as birds reached heavier weights, the MBM variability impacted performance.

Processing results and live production results were then used to produce gross margin which treatment 1 was $0.11 to $0.14 per bird greater than any other treatment.

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Dedication

I would like to dedicate my thesis work to my family. First off my parents, Chris and Sheila Eagleson, with their constant support whether it is emotional, financial, or physical needs. I would also like to thank my wife for her constant support, whether it be showing up to work early in the morning to bringing me dinner as I work, you have always supported me and given me the drive to push through.

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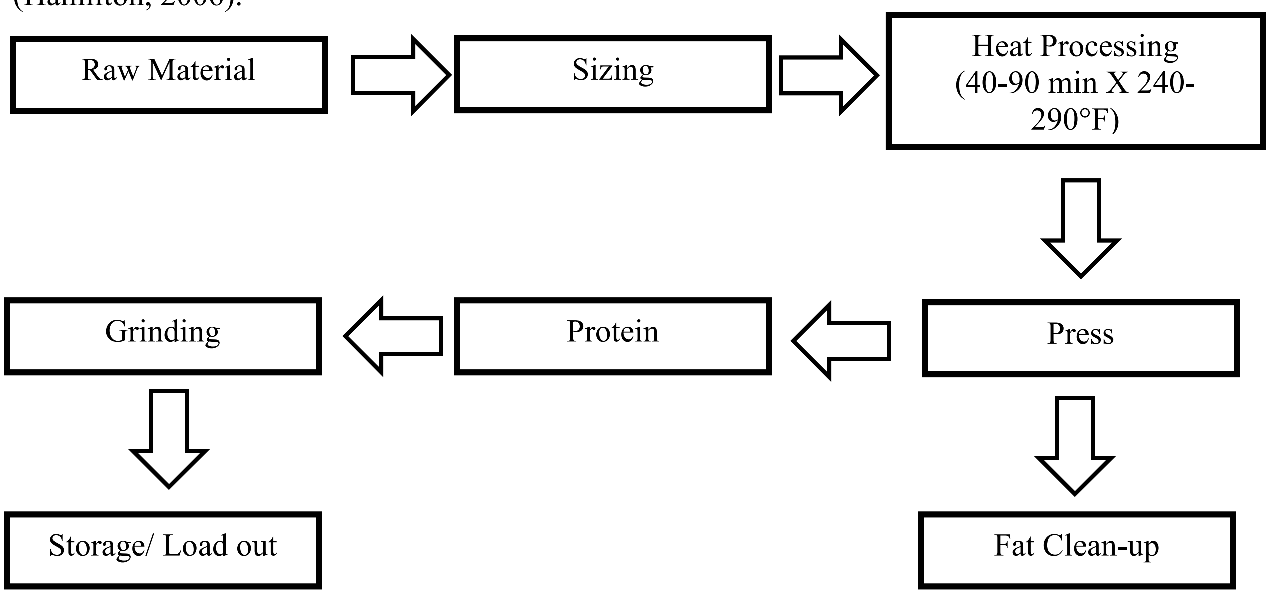
Literature Review

Introduction

Commercial poultry diets are composed of multiple feed ingredients and additives which are utilized at different inclusion rates by formulation programs to meet the nutritional requirements of different stages of growth and production. One ingredient, meat and bone meal (MBM), is a high quality protein source, but other characteristics make the meal valuable as well. These include digestible amino acids, fat, minerals such as calcium and phosphorus, and vitamins such as vitamin B_{12}. MBM also known as tankage is of animal origin.

In the United States there are 54 billion pounds of animal by-products produced annually (Meeker, 2006) originating from 4 million cattle and calves, 7 million pigs, and 100 million chickens and turkeys that are processed annually (ERS, 2001; NASS, 2001). Since only 51 percent of cattle, 56 percent of pigs, and 63 percent of chickens are edible for human consumption (Hamilton, 2006), the remaining by-products are processed into products such as MBM. The animal by-products as defined by Meeker and Hamilton (2006) are a secondary product obtained during the manufacture of a principal commodity. Though the animal by-products are not as valuable, the rendering industry has helped to add value by turning them into a feed ingredient which can be incorporated into the diets of poultry and swine. These animal by-products include: fat trim, meat, viscera, bone, blood, feathers, and hide. Most of the by-products are utilized as feedstuffs such as blood meal, meat and bone meal, meat meal, poultry meal, hydrolyzed feather meal, fish meal, and animal fats; but the main by-product is MBM. MBM as defined by the Association of American Feed Control Officials (AAFCO) is the rendered product of mammalian tissues including bone but exclusive of blood, hair, hoof, horn, hide trimmings, manure, and stomach and rumen contents (Hamilton, 2006). The only MBM permitted for use in ruminant animal feed in the United States is material that originates from plants that slaughter or process only non-ruminant materials due to Bovine spongiform encephalopathy, in which FDA published the feed rule (*Federal Register*: 21 CFR § 589.2000). There are processing factors that can affect the nutritional quality of the meat and bone meal. All of the rendering processes involve the application of heat, the removal of moisture, and the extraction of fat (Hamilton, 2006). The rendering process follows the flow shown in Figure 1 (Hamilton, 2006).



There are two different types of rendering facilities. There is a continuous-flow of which produces rendered material until there is no longer an input. The second kind is the batch system. The batch system is the use of one large oven for input of animal by-products to produce sterile output. Most North American rendering systems are the continuous-flow systems (Hamilton, 2006). The heat processing is the critical step in the production of the meat and bone meal. This step removes most of the moisture and inactivates most of the viruses, bacteria, protozoa, and parasites initially present. The cooking process can decrease the digestibility of the amino acids if not done properly. The cooking process is accomplished with steam at temperatures of 240°F to 290°F (115°C to 145°C) for 40 to 90 minutes depending on the system and raw materials (Hamilton, 2006). After heating, the material is put into the press, thereby extracting 90% of the total fat leaving 10% fat in the protein solids remaining (EPA, 1995). The material left is ground to a consistent size and distributed to feed mills or stored.

Rendering process contributes many valuable products to the feed industry such as fat and protein meals. However, the differences in the processing associated with the many operations processing by-products can attribute to the variability in the nutritional profile of the MBM products.

Amino Acid and Protein Quality

Protein levels in animal diets have long been monitored by producers to assure levels and quality are at the desired quantity. Protein levels in animal diets vary according to age of the animal. It is known that as the animal matures, protein needs diminish as tissue accretion slows. However, animals in production, such as dairy cattle or laying hens, still need a higher protein level. Transformation of protein into energy requires work by the body. The energy used by the body to break down protein can exceed the amount of energy produced. Thus, protein levels need to be monitored and balanced with dietary energy throughout the life of the animal.

Protein for animal diets primarily comes from two different sources: animal and plant protein. Plant proteins such as soybean meal (SBM) are widely used throughout the world as good quality protein sources for animal diets. Though widely used, SBM is limiting in methionine. Proteins from animal origins are typically highly digestible and have a nutritional profile which closely matches the essential amino acid needs of growing poultry and swine. Animal protein can be obtained from many different sources such as blood meal, feather meal, and fish meal, but MBM is the most widely used. MBM has drawbacks just as the plant based feed ingredients does with the varying protein quality.

Research done by Prange et. al. (1928a) showed that variations exist in the nutritive value of proteins from meat and bone scraps made by different manufactures. The earliest work done with MBM has shown that there are protein quality issues. This issue has continued through more recent work (Drewyor and Waldroup, 2000; Wang et al. 2014) with meat and bone meal. Protein quality, as defined by Boorman (1992), is the ability of a feedstuff to supply essential amino acids relative to an animal's metabolic needs. Reported protein values varied from 43.45 percent to 74.10 percent protein (N x 6.25) in an early commercial tankage digester (Prange et.

al., 1928b). The product with the highest protein showed the lowest ash content and vice-versa for the product containing the lowest protein levels.

Supplementing broiler diets with MBM provides nutrients such as vitamins, minerals, protein, and carbohydrates. Each of these is crucial nutrients of the broiler diet, but unfortunately the amount obtained from MBM can vary due to inconsistencies in quality. MBM is very desirable in broiler diets for its contribution of highly digestible phosphorus. The AAFCO states that there must be a minimum of four percent phosphorus with a calcium level not to exceed 2.2 times the actual phosphorus level (Hamilton, 2006). The incorporation of MBM into livestock and poultry diets spares the annual use of 2.6 billion pounds of mined and industrially manufactured feed grade phosphate compounds like dicalcium phosphate and deflourinated phosphate (Hamilton, 2006). Decreasing the amount of mined feed grade phosphate is not the only benefit from the high cost of mining feed grade phosphate. The protein contribution of MBM equaled decreasing corn production by three million less acres in 2002.

Kraybill and Wilder (1947) investigated the feeding value of meat scrap protein and found that some samples of meat scrap were deficient in methionine and tryptophan. The limiting amino acids identified in early research didn't account for the digestible amino acid content of the MBM, but just quantified the levels of each amino acid present. A comparison of the amino acid content of meat scrap by Almquist (1957), indicated that methionine and tryptophan were probably the amino acids which were limiting the growth of the chicks. Kratzer and Davis (1959) used ten different MBM sources as the main protein source in chick rations and found the addition of tryptophan and methionine improved performance.

While lysine is not a limiting amino acid with MBM, lysine is usually the first or second limiting amino acid in poultry feeds. The main factor regulating the total lysine content of animal protein is the composition of the rendered raw materials (Wilder, 1972). Heat treatment during the rendering process eliminates microorganisms, nutritional inhibitors, and improves overall digestibility by altering protein structure to allow enzymatic cleavage of the peptide bonds during digestion by animals. With lysine being the second limiting amino acid in broiler diets, easy determination of available lysine in MBM is important. Nordheim and Coon (1983) used multiple methods to determine available lysine.

Past research has shown that high quality MBM can be produced, however due to the raw material and processing methods the quality can still vary. For example, Parsons et. al. (1997) used 14 different meat and bone meal samples with the use of in-vivo and in-vitro assays to determine the quality of the protein. The meat and bone meal was analyzed to determine dry matter, gross energy, crude protein (N x 6.25), ether extract, ash, calcium, and phosphorus. Amino acids were also analyzed. Results indicated similar values as previously seen with the most limiting amino acids being the sulfur containing amino acids, cysteine and methionine (Parsons et. al., 1997). Parsons et al. (1997) determined that the ash content of the MBM was a good indicator of the protein quality. Parsons et al. (1997) showed more variability in the MBM than previous studies with the protein efficiency ratio varied from 0.6 to 2.9 compared with 1.7 to 3.0 in the study of Johnston and Coon (1979a).

Wang et al. (1997) wanted to further identify the limiting amino acids in the meat and bone meal. Three experiments were conducted to determine the order of limiting amino acid content. Their research discovered the order of most limiting to be: 1) tryptophan and the sulfur amino acids, 2) threonine, 3) isoleucine and phenylalanine + tyrosine, 4) methionine, 5) lysine, 6) valine and histidine. They also determined that supplementing tryptophan and cysteine was effective in improving the body weight of chicks fed MBM as the main protein source.

MBM can vary in composition or content of meat and bone. Eastoe and Long (1960) estimated that 83 % of the protein in bone is collagen. Boomgaardt and Baker (1972) and Berdanier (1998) have shown that collagen and gelatin (refined collagen) are deficient in most essential amino acids. Thus the bone content or ash content is going to have a negative effect on the protein quality due to the high collagen content and poor amino acid balance. The bone, however, is the source of the high phosphorus and calcium content. Thus, it is a balancing act for the rendering industry to keep the good calcium and phosphorus the poultry industry values, but also to keep the minimal amount of bone in the product to keep the protein quality high. Shirley and Parsons (2001) confirmed that crude protein and gross energy decrease as ash concentration increases and as the ash concentration increases the calcium and phosphorus content increases. In addition decreasing protein content means essential amino acid concentrations decrease with the exception of arginine (Shirley and Parsons, 2001). The decrease in essential amino acids and the increase in non-essential amino acids as the concentration of ash increases indicates that as the ash content increases, so does the collagen content. The increase of the non-essential amino acids in the high ash content MBM also results in a decreased digestibility of the meal. The decrease in digestibility had a negative effect on the protein efficiency value (Shirley and Parsons, 2001). The higher the ash content, the lower the digestible amino acid concentration, which was reflected in a lower chick body weight gain.

Karakas et. al. (2001) studied the differences in MBM originating from 3 pork and 3 beef sources. Species origin had no impact on the variability of the six meat and bone meal samples. The only observed difference was in the ash content of the pork meat and bone meal samples and results indicated that the species origin of the meat and bone meal does not impact quality like protein and ash content do.

The processing process can alter the digestibility of the amino acids, thus decreasing the quality of the protein. Widyaratne and Drew (2011) investigated the effects of protein level and digestibility on growth performance and carcass characteristics of broiler chickens. The diets consisted of high protein with high digestibility and low digestibility as well as low protein with high digestibility and low digestibility. The results suggests that the use of highly digestible feed ingredients when formulating low-protein diets may significantly reduce the negative effects of low-protein diets on the growth performance of broilers (Widyaratne and Drew, 2011). This could be the reason that birds fed a high ash content MBM lack in growth performance.

Muir et al. (2012) has shown the improvements in which the high quality proteins from MBM can be beneficial for bioactivity. The gavage of protein fractions were administered 4 times during the first week post-hatch. The improved body weight, breast weight, and increased intestinal length have indicated improvement that the MBM has beneficial effects over the control. Though not applicable in the industry to give protein fractions to individual birds, Muir et al. (2012) has shown that the MBM contains growth promoting bioactivity.

Variability in protein sources in nutrient profile and structure may have differential effects in the nutrient utilization, metabolism, and subsequent growth of broilers. Wang et al. (2014) studied the effects of dietary protein source, amino acid density, and apparent metabolizable energy levels on growth and carcass performance. Diets were formulated with either MBM or distiller dried grains with solubles (DDGS) in either a low or high density of protein. Studies have shown that high nutrient density diets lower the feed intake of birds (Wang et al., 2014). The results also indicate that broiler chickens fed DDGS exhibit a wider range of feed conversion ratio response to nutrient density than those fed an MBM diet (Wang et al., 2014). Carcass yield indicates there was not a significant difference, but the lower intake of feed with the high density diets lower broiler meat production costs. In further studies, Wang et al. (2015) indicated that the high density diets may improve performance without affecting their intestinal structure.

Inclusion Rates

Varying compositions of MBM can mean that including MBM of unknown nutritional profile into poultry rations could affect growth. In the early studies, the effects of feeding MBM were observed and compared to that of an equal amount of protein derived primarily from vegetable sources. Results showed that the diets containing animal protein of a known nutritional profile supported better feed efficiency and growth rates and were therefore more profitable to use (Wheeler, 1898). This work initiated investigations to determine the limitations of MBM as a feed ingredient.

Prange et al. (1928a) used different inclusion rates of MBM, replacing from 8 to 15 % of the dietary protein. The greatest growth was observed when 10 to 12 % of the total protein of the diet was sourced from animal origin source. The available protein was reported to be of excellent quality, thus resulting in better bird performance. Later work done has shown that the limiting amino acids of the diet are those limiting in the MBM when the inclusion rate is above 10 % of the diet (Skurray, 1974). Martosiswoyo and Jensen (1987) observed that there was higher metabolizable energy value when diets contained 20 % of MBM versus 40 %. This supports other research indicating that lower percent's of dietary animal protein give better growth. Dolz and De Blas (1992) showed a decrease of the average apparent metabolizable energy content of meat and bone meal by 5.5% at increased inclusion levels from 6 to 12%. The apparent metabolizable energy for the 10 and 20 % percent MBM inclusion rate of the diet show the same results as in the previously cited research that the lower inclusion rate showed an increase in apparent metabolizable energy (Karakas et al., 2001), further indicating that the lower inclusion rates of the meat and bone meal supports good bird performance.

Further studies were conducted to determine the influence of different inclusion rates of MBM containing 42.03% crude protein and 38.23% crude ash on performance of broilers from 22-42 days of age (Bozkurt et al., 2004). The inclusion rates of the period were 2, 3.5, and 5%. Results indicate that the 5% MBM supplementation increased body weight and body weight gain of broilers. The 3.5 and 5% supplementations to diets were higher in carcass yield than those of 2% MBM. The treatments that contained MBM gave a better carcass yield than the treatments containing no MBM (Bozkurt et al., 2004). These results indicate up to 5% inclusion of MBM can be used successfully during the grower period in broiler diets.

Energy Quality

Olson et al. (1961) discovered that when MBM were fed in high quantities to broilers; metabolizable energy notably decreased. This happened even when the necessary vitamins and minerals were added. When compared to soybean oil meal, the MBM provides higher metabolizable energy until the percent protein of the assay diet reaches levels above 45%. At this level, the MBM falls below the metabolizable energy of the soybean meal. The reason for the dropping of the metabolizable energy of the MBM is believed to be caused by flushing due to the birds ingesting abnormally high levels of certain proteins.

The apparent metabolizable energy of meat and bone meal is one that is said to be hard to determine at levels used by the poultry industry (Martosiswoyo and Jensen, 1988b). According to Martosiswoyo and Jensen (1988a), Hill et al. found levels of substitution of at least 20% but 40% is recommended for determining metabolizable energy. Including MBM at these levels greatly unbalances the diet with respect to calcium and phosphorus (Martosiswoyo and Jensen, 1988a). Therefore as the level of substitution of MBM in the diet increases, the ability to estimate the metabolizable energy value of the ingredient decreases (Olson et al., 1961; Lessire et al., 1985; Martosiswoyo and Jensen, 1988). The decrease in metabolizable energy could be attributed to many sources: 1) interference of the high calcium content with fat absorption, 2) decreased absorption of fatty acids associated with an increased saturated: unsaturated fatty acid ratio, 3) an increasing amino acid imbalance, 4) decreased digestibility of meat and bone meal protein caused by the high mineral content, 5) a reduced feed intake resulting in greater metabolic and endogenous energy losses in relation to the energy of the test ingredient, and 6) a combination of these factors (Martosiswoyo and Jensen, 1988a).

Experiments were conducted to determine the reason for declining energy estimation associated with increased dietary MBM levels. Simulated MBM was used in this test. After feeding studies, Martosiswoyo and Jensen (1988a) discovered that different levels of substitution for the basal diet did not result in a lower energy value at the higher substitution level. The simulated MBM with the removal of mineral matter significantly increased the energy value of the organic portion of the ingredient in one metabolizable energy trial and also in the true metabolizable energy trials (Martosiswoyo and Jensen, 1988a). The reduction in the metabolizable energy in the MBM associated with the higher level of substitution does not appear to be due to a simple interference with dietary substitution of fat or amino acids or both or to a wider ratio of saturated to unsaturated fatty acids (Martosiswoyo and Jensen, 1988a). Further experiments determined that the reduction in metabolizable energy level of meat and bone meal was not due solely to the fat content of this ingredient (Martosiswoyo and Jensen, 1988a). Reduced energy values were still observed when the fat levels were reduced. Also, the underestimation of metabolizable energy of MBM meal at higher substitution levels does not appear to be explained by a marked alteration in protein digestibility. Lessiere et al. (1985) observed no significant effect on feed intake when adult roosters were fed diets with levels of MBM from 0 to 60%; yet marked decline in apparent and true metabolizable energy was observed as the inclusion rate of MBM increased from 5 to 20%. Thus differences in feed intake cannot be attributed to the underestimation of metabolizable energy of MBM. Sibbald and Slinger (1962) failed to obtain evidence that amino acid deficiency or excesses had a direct effect upon metabolizable energy values. The reasons for declining energy estimates associated with increased dietary MBM levels have been further explained with the above experiments, but the reason is still undetermined exactly as to why the decline occurs.

Practical broiler rations with underestimated energy values will lead to a wider calorie: protein ratio and to excess fat deposition (Martosiswoyo and Jensen, 1988a). In a follow up study, MBM assigned different metabolizable energy values was formulated to determine the response to performance and abdominal fat deposition in broiler chicks. The metabolizable energy listed in the United States-Canadian Tables of Feed Composition: Nutritional Data for United State and Canadian Feeds, Third Revision (1982) is 2062 kcal/kg. A value between 2300 and 2500 kcal/kg was suggested as a more appropriate value for meat and bone meal when used at practical levels in balanced poultry diets (Martosiswoyo and Jensen, 1988b). The underestimation of the metabolizable energy of the meat and bone meal has led to excess fat deposition in male broilers. Garrett (1976), in a survey regarding oily bird syndrome, found that the problem was more severe when high levels of animal by-products were used in the diets. Thus the metabolizable energy value used at this time to formulate was in need of updating. According to the National Research Council (1994), values were set that were more representative of the true energy values.

Dolz and De Blas (1992) have reported that metabolizable energy is not going to be dependent on the type of animals or by the method of rendering used to produce the MBM. They determined it is the inclusion rate of the meal which determines metabolizable energy. Dale (1997) determined that a consistent increase in energy was observed when meals were evaluated as separate fractions. Generally, the improvement was between 8 and 16%. Thus, the composition of the meat and bone meal can have an effect on the metabolizable energy of the rations. Dale (1997) supports the conclusion of Martosiswoyo and Jensen (1988a) that the metabolizable energy value of meat and bone meal is considerably higher than that reported in many nutrient composition tables. Reducing the compounding effect of the high levels of calcium and phosphorus can yield a more realistic estimate of the digestibility of the meat and fat component. Thus the lower the inclusion rate of the MBM, the more likely it results in a metabolizable energy level that is much more realistic of the practical broiler diet rations.

Garcia et al. (2012) has investigated whether methods for analysis of particle size and protein digestibility can improve prediction of apparent metabolizable energy (AME) for ducks. The particle size was determined using Ro-Tap to shake the sample through the sieves to determine the particle size. The #20 and #35 sieves were used to determine the particle size. Pepsin-HCl solution was used to determine the nitrogen content which was then converted to protein with the 5.37 conversion factor. Results indicate that the proximate composition with particle size data can be used to produce accurate predictions of AME for ducks (Garcia et al., 2012). Further studies with larger numbers of samples and other poultry species could produce a validated method that would provide nutritionist with routine access to useful data on MBM energy (Garcia et al., 2012).

Testing Methods

Since Wheelers (1898) work showing that animal products provide beneficial protein for the growth of chicks, there has been a need for determining the quality of the MBM. The difficulty with testing MBM is the variability that can occur. The different sources and the different processing procedures that occur can help to alter the quality of the MBM. There have been multiple attempts to develop a different test to determine the quality of MBM with in-vivo and in-vitro testing.

Some of the earliest work to determine values for MBM was done by March et al (1948) determining that the nutritional value varies greatly according to the protein quality index method of the evaluation (Almquist et al., 1935). Kokoshi (1947) reported a similar range of variation in protein index values as Almquist et al. (1935). March et al. (1948) used three different tests to evaluate the quality of MBM. The test was a feeding study to determine growth with difference basal diets of corn and wheat with addition of animal or fish by-products to reach a protein level of 17 %. They then determined the protein index values according to Almquist's method (Almquist et al., 1935). Also the amino acid assay was determined in-vitro by means of microbiological assays. According to the results of all three methods, there was considerable variation in the nutritive value of the fish meals and meat meals (March et al., 1948). It is also suggested that an amino acid analysis based on acid hydrolysis of the total protein corrected for the indigestible and the non-protein fractions would indicate the biological value of animal protein concentrations (March et al., 1948). The test that has held over time for determining protein quality continues to be chick bioassays.

The chick bioassays take long periods of time to complete. Thus Choppe and Kratzer (1962) focused on determining a method that correlated with the chick bioassays, but was much quicker in time. Since gelatin is the predominant protein in the hot water-soluble fraction of MBM (Almquist et al., 1935), Choppe and Kratzer (1962) thought that a determination of the percentage of protein which was hot water-soluble might be useful as a test for feeding quality. Fraenkel-Conrat and Cooper (1944) found that Orange-G dye combines stoichiometrically with free amino, imidazole, and guanidyl groups in an intact protein. Overheating of the protein caused the free amino group to become unavailable for reaction with the dye. Therefore the binding capacity of the meat and bone meal would be a good indicator for the protein quality. The feeding of the purified diets containing MBM to the chicks for growth showed that a feeding value to have considerable variation. Even though there was considerable variation in the feeding values as indicated by chick growth, there was a significant correlation between a combinations of the Orange-G and hot water-soluble proteins compared to the chick growth to predict the growth value (Kratzer and Davis, 1959).

Nordheim and Coon (1984) continued the pursuit to find a quick and easy way to determine the nutritional quality of the MBM at the rendering plant. They looked at the idea of using available lysine to determine the quality of meat and bone meal. The standard for determining available lysine is chick bioassays which is costly and slow. Nordheim and Coon (1984) compared digestible lysine, chick bioassays, 1-flouro-2,4-dinitrobenzene, and 2,4,6-trinitrobenzene sulfonic acid for determining the available lysine. The meaning and amount of available lysine determined by each technique is different. Although variation occurs, there is a correlation between each technique and the chick bioassays (Nordheim and Coon, 1984).

A collaborative study by Engster et al. (1985), used six different laboratories to evaluate a precision-fed rooster assay as a means of measuring biological availability of amino acids in a variety of feedstuffs for poultry. Identical samples were sent to the six labs for the analysis of the true amino acid availability by the precision-fed rooster assays. There was a relatively high degree of variability among laboratories in the total amino acid values determined for the same ingredient. The meat meal sent to the laboratories varied in metabolizable energy. The differences in energy values should not be interpreted as an indication of differences in protein quality, because the true amino acid availability values of these meat meals was nearly identical (Engster et al., 1985).

Some of the easiest and most cost effective testing is pepsin digestibility. Pepsin nitrogen digestibility assay (AOAC, 1980) was determined to be an effective use for monitoring quality of MBM, particularly low-quality samples. Davis et al. (2015) reevaluated the pepsin nitrogen digestibility assay for detecting difference in amino acid digestibility among MBM. The pepsin nitrogen digestibility assay was determined to be only valuable in determining large differences in protein quality among MBM when levels of 0.02 and 0.002% pepsin are used (Davis et al., 2015). The pepsin assay is still great for determining if the MBM is of low or high protein quality, but the inability to determine small differences makes the pepsin assay not great for determining true amino acid digestibility.

With the high variability of MBM, there has been a search for a method to determine amino acid digestibility as an easy determination of protein quality. Standardized ileal broilers assays (SIAAD) was developed using 3 week old broilers (Lemme et al., 2004). Since the development of the new assay, comparative studies of the assays have been conducted. The SIAAD has been compared to the precision-fed cecectomized rooster assay (PFR), precision-fed ileal broiler assay (PFC), pepsin digestibility, and poultry complete IDEA (PC IDEA) for determining amino acid digestibility of feedstuffs. Kim et al. (2012) has determined that the PFR, SIAAD, and PFC all seem to be acceptable methods for determining amino acid digestibility of feedstuffs. Rochell et al. (2013) indicated significant relationships of PC IDEA and pepsin digestibility with SIAAD to determine the amino acid quality in MBM. Further research to broaden the database would be needed to enable the prediction equations Rochell et al. (2013) determined to predict amino acid availability. Davis et al. (2015) determined that the PFR and PFC are acceptable methods for determining and detecting differences in amino acid digestibility among MBM samples.

Further research has been done to determine the effect of strain and age of the broiler on the ileal amino acid digestibility of meat and bone meal. Kim and Corzo (2012) determined that the age used for ileal amino acid digestibility was significant in broilers, but the sex was not significant. Adedokun et al. (2014) used the SIAAD to compare the values between broilers and laying hens. The results suggest that differences exist in the digestibility capabilities of laying hens and broilers, which indicates that species to species nutrient digestibility values or adjustments may be needed.

Summary

Meat and bone meals have been found to have many nutritional qualities that contribute to the growth of poultry. Although variable due to the starting ingredients and processing system used, the meat and bone meal can be successful to increase the nutrients of the diet. Nutritional factors, such as protein and minerals, can be supplied to broilers in highly bioavailable in the diet. However, variability in MBM does exist in quality factors such as protein, mineral and energy content primarily due to raw material input differences as well as differences in the production of the meal. The goals of this experiment were to quantify how much broiler chick performance could be influenced when the diet contained MBM that differed from the nutritional values used in the dietary formulations and compare this to a diet based on a MBM prepared with a high level of quality assurance so that each batch has minimal variability.

As long as the animal production continues, there will be a constant supply of meat and bone meal for the poultry industry. The meat and bone meal supplies the industry with an economically favorable solution for protein and also an excellent source of calcium and phosphorus.

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Evaluation of the Impact of Meat and Bone Meal Nutritional Variability on Broiler Performance

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Summary

Due to the variability of raw ingredient inputs into meat and bone meal (MBM), the nutritional composition of each batch can vary. The objective of this trial was to determine if the nutritional variability of meat and bone meal has an impact on performance and yield. Twelve hundred day-old male broilers from the Cobb 500 female line were randomly allocated to 48 pens (25 chicks/pen/22 square feet) and grown for 49 days. The four dietary treatments provided were: 1) H.J. Baker proprietary blend, ProPlus 57 fed continuously; 2) formulated for MBM 50 fed continuously; 3) formulated for MBM 50 but starting at day 14, the MBM was rotated between MBM 45, 50 and 55 with no adjustments for the formulation to compensate for any nutritional differences: 4) formulated for MBM 50 but MBM 45 was used in the actual diet. Each pen was provided feed and water *ad libitum* throughout the grow-out period and birds received a diet series based on the Cobb nutritional standards. All birds received a coccistat through the feed. All other aspects of the grow-out followed industry standards. Birds were weighed on days 0, 14, 28, and 49 and feed consumption data was also collected for this period. Birds were processed on day 50 and live weight, pre-chill, post chill, breast major and minor, wings, leg quarters, and skeletal weights were all collected for individual birds. Data were analyzed using PROC GLM with dietary treatment serving as the main effect. Treatment 3 and 4 average weights were significantly lower (P=.0142) at day 49 than treatments 1 and 2. There

were no significant differences at days 0, 14, or 28. There was a significant difference in feed conversion at day 14 (P=.0397) and 28 (0.0003). Processing showed no significant difference in live weight, pre-chill, post chill, major and minor breast, wings, or leg quarters, but there was a significant difference (P=.0352) in the skeletals. These results suggest that while nutritional variability did not influence early performance, as birds reached heavier weights, MBM variability impacted performance causing birds to lag in final weights as much as 80 grams.

INTRODUCTION AND OBJECTIVES

MBM has been used as an ingredient in broiler diets for almost 100 years (Wheeler, 1828; Kraybill, 1928; Prange et al., 1927; 1928a; 1928b; Kratzer and Davis, 1959; Skurray, 1974). Highly digestible meat protein blends are beneficial to growth and feed conversion not only because they more precisely reflect the amino acid requirements of rapidly growing broilers, but blended meat protein ingredients can help reduce enteric challenges. Particularly, during early growth periods when high protein diets are necessary and are often achieved by higher inclusions of soybean meal, which contains non-starch polysaccharides that are not well digested, can be contributed to enteric issues particularly when birds are stressed by such challenges as coccidia. The benefits would be much higher if the supplements are of high quality, easily digestible and bioavailable.

The MBM dietary inclusion rates vary but Martosiswoyo and Jensen (1988) reported that inclusion of MBM up to 10% did not increase abdominal fat weight of broilers. There can be significant protein variability in different batches of MBM (Drewyor and Waldroup, 2000) and due to the high flow through of ingredients into finished feed for most commercial poultry feed mills, it is difficult to impossible to continuously adjust the formulations to account for ingredient nutritional fluctuations. Wang et al. (2015) reported that the high amino acid and apparent metabolizable energy densities in grower diets from 8 to 21 days can improve the growth performance. If the feeds prepared with ingredients that do not meet the targeted nutritional specification will mean the diets are not optimal in amino acid and apparent metabolizable energy, thus potentially hindering the growth performance of the birds.

H.J. Baker has developed a proprietary process for producing a high quality, consistent animal protein meal composed of ruminant, porcine & avian animal protein byproducts which is marketed as H.J. Baker ProPlus 57(Table 1.). It also contains the antimicrobial Termin-8® as well as the antioxidant, Santoquin® Plus (150 ppm ethoxyquin, 200 ppm BHT). (H.J. Baker, 2014). MBM 50 is a 50% protein meal that is commonly used in the poultry industry but communication with commercial poultry nutritionists indicated that while this may be the ingredient requested, the protein level can vary from 45 to 55% on incoming batches. The first objective of this study was to determine the impact of H.J. Baker's (HJB) ProPlus 57 on the growth, performance, and carcass characteristics of broilers. The second objective was to determine what the impact would be on broiler performance when the nutritional profile of MBM added into the diets is not consistent.

EXPERIMENTAL DESIGN

The experimental design included four dietary treatments with twelve replicates (Table 2). Treatment 1 received the HJB proprietary blend, ProPlus 57 continuously at the inclusion rates of 10, 7.5 and 5 % in the starter, grower and finisher diets, respectively. Treatment 2 was formulated to contain Meat and Bone Meal 50 (MBM50) fed continuously and also at the same inclusion rates of the diets as the ProPlus 57. Treatment 3 (MBMV) was formulated utilizing the nutritional profile of MBM50 but starting at day 14, the MBM50 was replaced in the diet with either a MBM with 45% or 55% protein (MBM45 or MBM55) but without altering the MBM50 dietary formulation to compensate of nutritional differences. The schedule of changing the diets is shown in Table 3. Treatment 4 (MBMV45) consisted of a diet series in which the diets have been formulated using the nutrient profile for MBM50 but the MBM containing 45% protein was used in the actual diets and also fed at 10, 7.5 and 5% of the starter, grower and finisher diets respectively. Diet compositions are shown in Table 4 and nutrient compositions in Table 5. The Proximate analysis results for the diets are shown in Table 6.

ANIMAL HUSBANDRY

The trial location was a floor pen facility (Barn 232 West) at the University of Arkansas System's Division of Agriculture Poultry Science Department Research Farm in Fayetteville, Arkansas. This project was conducted under the guidance and approval of Institutional Animal Care User Committee under number 14051.

Chicks

Twelve hundred newly hatched broiler chicks (males off Cobb 500 female line) were obtained from a local hatchery and conveyed directly to the research facility at the University of Arkansas Poultry Farm. Chicks were reared at a stocking density of 0.84 sq. ft. / bird as specified in the FASS Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (Anon, 1999). Chicks were randomly allocated to 48 pens (25 birds/pen) located in an environmentally controlled barn. Twelve pens were randomly assigned to each of the 4 treatments. Two chicks were selected from each of the 12 boxes of day old chick with an additional chick randomly pulled from one more box. Only healthy appearing chicks were used in the study. No birds were replaced during the course of the study. Birds were grown to 49 days of age.

Management

Birds were reared under a ventilation and temperature regimen reflecting industry standards. Chicks were started at a temperature of 90°F and the temperature lowered by 1°F daily until a temperature of 65°F was achieved or as close as possible given the natural environmental temperatures. The birds were provided with 20 hours of light per day for the first seven days followed by 6-hour dark period for the remainder of the trial. A record of daily maximum and minimum temperature and relative humidity in the barn were obtained for the entire period of the study.

The pens were provided with new kiln dried pine shavings at a depth of 3-4 inches per pen as bedding. Each pen was provided with one hanging feeder equipped with a Choretime® revolution feed pan and one Choretime® standard flow nipple drinker line complete with regulator and four nipple drinkers. Water flow through the nipple drinkers was adjusted weekly to provide optimum flow as per the Choretime drinker specifications. The birds were given access to experimental diets and water for *ad libitum* consumption.

Birds were checked a minimum of twice daily for any abnormalities and availability of feed and water. Any dead birds were removed from pens and the date of death, weight, and probable cause of death recorded. Birds were culled only to relieve suffering. All the culled birds during the course of the study were weighed and the weight, date of cull, reason for cull recorded.

Feed

Diets were formulated to meet the nutrient requirements based on the recommendations of Brazil Standards (Rostagno, 2011). Major ingredients (corn, soy and DDGS) were analyzed for nutritional content before formulating the diets and this information was used in diet formulations. A starter diet was fed from days 0-14, grower diet from days 14-28, and finisher diet from days 28 to 49. All diets were pelleted, and the starter diet was also crumbled.

Throughout the trial, the MBMV ration was formulated using the MBM50 ingredient nutrient specifications (Treatments 3 and 4). As explained previously, after the starter period, for Treatment 3, the MBM50 diet was rotated with diets containing MBM45 or MBM55 and for Treatment 4, the MBM50 was replaced with MBM45 throughout all the feeding periods without nutrient rebalancing the ration.

DATA COLLECTION

Growth and performance

Birds were group weighed by pen on day: 0, 14, 28, and 49 and average weight per bird, and average weight gain per feeding phase calculated. Feed provided to each pen was weighed and recorded. Feed was weighed back on d 14, 28, 49 and feed consumption and feed to gain ratios (FCR) were calculated (FCR was adjusted for mortality).

Carcass yield and quality

Birds were processed at 50 days of age. Five birds per pen were randomly selected during d 49 weigh for processing. No birds with obvious signs of defects were selected. All the birds used for processing were individually weighed and double wing banded to maintain the identity of the birds. Feed was withdrawn approximately 10 hr. prior to processing. On the day of processing, birds selected for processing were transported in clean coops to the processing plant. Birds were individually weighed prior to shackling, then stunned via a 12 volt electrical bath, and killed via exsanguination. After feathers and viscera were removed, a hot carcass weight was obtained and then carcasses were chilled in an ice bath for 2 hours. Post chilling, the whole carcass was re-weighed and then breast major and minor, wings and leg quarters were separated and weighed.

STATISTICAL ANALYSIS

Statistical analysis was carried out using SAS® software (version 9.4, SAS institute INC., Cary, NC). Data were analyzed using the GLM procedure with dietary treatment serving as the main effect with α set to 0.05. Treatments were separated using Fisher's least significant difference test. Live production parameters analyzed included average weight at days 0 (initial weight of chicks), 14, 28, and 49, gain for 0-14, 14-28, 0-28, 28-49, 0-49 days as well as percent livability for 0-14, 0-28, and 0-49 days. Processing parameters analyzed included selection weights prior to processing on day 50, hot carcass without giblets (WOG), chilled WOG and parts including breast, tenders, wings, leg quarters, and skeletal. In addition parts yield was calculated by dividing the absolute weights of each part by the chilled WOG and multiplying by 100.

Results and Discussion

Live Results

The live production results are shown in Tables 7 to 10. Initial average weights were similar and no differences in average weights were found at days 14 (P=.7876) and 28 (P=.1127) (Table 7). Initial weights on day 0 were statistically similar (P=.3031) and within 0.4 grams ranging from 44.6 grams for the MBM50C to 45 grams for the Proplus57 diet. Differences were present by day 49 (P=.0142) with the ProPlus 57 and MBM50 diets supporting the heaviest birds (3.805 and 3.793 kg, respectively) and followed by the MBM50V and MBM45 which had similar weights (3.724 and 3.721 Kg, respectively). These results indicate that while nutritional variability did not influence early performance, as birds reached heavier weights, the MBM variability impacted performance causing birds to lag in final weights by as much as 80 grams or almost 0.2 lbs. The weight gain was calculated by subtracting the initial weight from the average weight on days 14, 28 and 49 (Table 10). No treatment differences were observed from the 0-14 period weight gain (P=.7724) but for the 14-28 day period as well as the 0-49 days period, differences were observed (P=.0344 and P=.0124, respectively). For the 14-28 day gain, the ProPlus 57 had the highest weight (1.224 kg) which was similar to the MBM50C and MBM50V (1,217 and 1.197). The MBM50V was similar to the MBM45 which had the lowest weight (1.185). For the 0-49 day gain, the ProPlus 57 supported the greatest gain, 3.760 but this was similar to the MBM50C, 3.749 and then the two variable diets supported lighter weights (3.768 and 3.767). The 28-49 day weight gains, the ProPlus 57 supported the heaviest gain, 2.151 with the MBM50C similar at 2.143 and the two variable diets supported lighter weights (2.096 and 2.110). The feed-to gain ratios were calculated by dividing feed consumed (either cumulative or for the period) by the total weight including mortality weight at each age (Table 8). For the 0-14 day period, the MBM45 had a significantly higher ratio than the MBM50C or MBM50V but was not different from the ProPlus 57 (P=.0397). By the 0-28 period or the 14-28 day period, the MBM45 feed to gain ratios were significantly higher than the other diets (P=.0003 and P=.0034, respectively). No differences were observed for the 0-49 or 28-49 day periods. No differences were found in feed intake for the 0-14, 14-28 or 0-28 day (P=.5862, .1648 and .3365, respectively; Table 9). The 0-49 day or 28-49 day feed intakes were different with the ProPlus 57 fed birds consuming the most feed but having a statistically similar consumption to the MBM50C fed birds. The MBM50C birds consumed a similar amount to the MBM45 birds which were similar to the MBM50V birds who consumed the least amount for these periods.

Processing

Day 50 slaughter weights were approaching significant differences (P=.1098) with the ProPlus 57 birds heaviest and MBM45 the lightest (Table 12). Pre-chill and post chill carcasses without giblets were not significantly different for any of the treatments. Table 13 shows the weight of the processed parts. For absolute weight of parts, no differences were observed for the skinless breast or tenders, however, tenders and wings were approaching significant differences (P=.0917, .0809, respectively) with the ProPlus birds yielding the heaviest tenders and wings and the MBM45 yielding the lightest of these parts. The skeletals were heaviest for the ProPlus 57 birds followed by the MBM50C (P=.0352) with the MBM45 being similar to the MBM50C and the MBM50V (790.9, 773.95, 766.9 and 760.4 respectively). The heavier skeletal weights were attributed to the unharvested meat remaining, particularly the oyster shaped meat below the backbone and above the wings. This would be meat typically captured in the Mechanically Deboned Meat process in processing plants. There were no differences in the percent yield (Table 14).

Economic Analysis

Data from the trial were used in the interpretation of an economic analysis to determine cost margins. The feed formulation (Table 4) for each treatment and the resultant costs per kilogram by treatment using May, 11 2015 market prices are presented in Table 15. Processing data were used to extrapolate a cost for the whole bird without giblets (WOG). The Georgia dock prices for May 11, 2015 were used to determine price for each part of the bird and the WOG value (Table 16). Combination of Tables 15 and 16, and adding the May 11 prices for parts, results in an interesting summation for the economic evaluation of the results (Table 17). Gross margin, that is, revenues from harvested meat minus the feed costs, for the ProPlus 57 treatment was greater than that for any treatment by $0.11 to $0.14 per bird. MBM50 treatment was greater than the other variable MBM by $0.004 to $0.0289 per bird (Goodwin H.L., 2015).

Discussion

In conclusion, MBM needs to be tested for proper nutritional value upon arrival to the feed mill and should be used in the formulation of the feed. The potential for higher weights at day 49, when properly formulated with nutrient content, will be economically beneficial to the poultry companies. This is apparent in the economic evaluation in the birds that were formulated for proper nutrients were margins larger than those birds fed the variable MBM diets. Feed conversion and properly checking MBM for nutritional content can be a cost saving measure because better quality ingredients lead to reduced FCR early in life.

Field reports suggest that the birds fed the ProPlus 57 outperformed the other birds in body weight, weight gain, processing yield, and had a gross margin greater than that of other treatments by $0.11 to $0.14 (Hill, 2015). It is also evident that the birds that received proper formulation for MBM benefited in greater body weight, weight gain, processing yield and had a greater gross margin than the variable MBM by $0.004 to $0.0289. In an industry with small profit margins this gross margin difference can add up in time.

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Tables

Table 1. Composition of H.J. Baker's ProPlus 57

Assay	H.J. Baker's Pro Plus 57 Animal Protein Concentrate As Is Value	Digestible (%)
Moisture	5.20	
Protein (%)	57.00	50.49
Fat	8.33	
Metabolizable Energy (Kcal/kg)	2724.91	
Ash (%)	24.28	
Calcium (%)	7.91	
Phosphorus (%)	3.96	
Phosphorus, Available (%)	3.96	
Sodium (%)	.43	
Lysine (%)	2.88	2.288
Methionine (%)	0.56	0.439
Methionine + Cysteine (%)	1.70	1.079
Threonine (%)	1.94	1.418
Phenylalanine (%)	1.95	1.573
Tryptophan (%)	0.34	0.266
Cysteine (%)	1.14	0.639
Valine (%)	2.69	2.129
Isoleucine (%)	1.79	1.472
Leucine (%)	3.51	2.817
Histidine (%)	0.77	0.532
Arginine (%)	3.47	2.818

Ingredients: Ruminant, Porcine, and Avian Animal Protein By-Products, Steamed Bone Meal, Biolys 60®, Termin-8®, and Santoquin® (330 ppm)

Table 2. Experimental Design

Treatment	Description Formulation Base	Starter Diets	Grower/Withdrawal Diets	Total No. of pens /trt	No. of birds/pen
1	Control-ProPlus 57	PROPLUS 57	PROPLUS57	12	25
2	MBM50	MBM50	MBM50	12	25
3	MBMV	MBM50	Diets will rotate between MBM50, MBM45 and MBM55 (See schedule)	12	25
4	MBMV45	MBM50	MBMV45	12	25

Table 3. Schedule for diet changes for treatment 3 starting at day 14

Treatment	Day	Diet
3	14	MBM45
3	17	MBM55
3	20	MBM45
3	23	MBM50
3	26	MBM45
3	29	MBM55
3	32	MBM50
3	35	MBM55
3	38	MBM50
3	41	MBM55
3	44	MBM45
3	47	MBM50

Table 4. Composition (g/kg) of diet with ProPlus 57 and 50% Meat and Bone Meal.

Ingredient	Starter		Grower		Finisher	
	PP57	MBM50	PP57	MBM50	PP57	MBM50
Yellow corn	659.69	635.40	688.45	673.97	702.65	693.81
Soybean meal 47%	216.52	236.14	201.20	215.52	197.13	206.59
ProPlus 57	100.00	0.00	75.00	0.00	50.00	0.00
Meat and bone meal 50	0.00	100.00	0.00	75.00	0.00	50.00
Poultry oil	8.13	15.40	15.73	19.77	25.05	27.43
Dicalcium phosphate	0.00	0.00	2.21	0.00	6.05	3.59
Limestone	2.67	0.00	5.86	4.15	7.53	6.96
Salt	3.30	2.84	3.60	3.25	3.89	3.66
DL-Methionine	2.60	2.90	2.43	2.65	2.46	2.61
L-Lysine HCl	3.53	3.39	2.32	2.22	2.14	2.07
L-Threonine	0.81	1.18	0.45	0.72	0.35	0.53
Mintrex P_Se[1]	1.00	1.00	1.00	1.00	1.00	1.00
Choline Cl 60%	1.00	1.00	1.00	1.00	1.00	1.00
Coban 90[2]	0.50	0.50	0.50	0.50	0.50	0.50
2X broiler premix[3]	0.25	0.25	0.25	0.25	0.25	0.25
TOTAL	1000	1000	1000	1000	1000	1000

1. Provides per kg of diet: Mn (as manganese methionine hydroxy analogue complex) 40 mg; Zn (as zinc methionine hydroxy analogue complex) 40 mg; Cu (as copper methionine hydroxy analogue complex) 20 mg; Se (as selenium yeast) 0.3 mg. Novus International, Inc., St. Louis MO 63141.
2. Elanco Animal Health division of Eli Lilly & Co., Indianapolis, IN 46825.
3. Provides per kg of diet: vitamin A (from vitamin A acetate) 7715 IU; cholecalciferol 5511 IU; vitamin E (from dl-alpha-tocopheryl acetate) 16.53 IU; vitamin B_{12} 0.013 mg; riboflavin 6.6 mg; niacin 39 mg; pantothenic acid 10 mg; menadione (from menadione dimethylpyrimidinol) 1.5 mg; folic acid 0.9 mg; thiamin (from thiamin mononitrate) 1.54 mg; pyridoxine (from pyridoxine HCl) 2.76 mg; d-biotin 0.066 mg; ethoxyquin 125 mg.
4. Diets containing MBM45 or MBM55 were prepared using the MBM50 diet formulations but replacing the MBM50 with either the MBM45 or MBM55

Table 5. Calculated nutrient content of diets with different meat byproducts.

Nutrient	Starter		Grower		Finisher	
	PP57	MB50	PP57	MB50	PP57	MB50
	(%)					
Crude protein	22.40	22.55	20.28	20.40	18.74	18.83
Calcium	**0.90**	0.95	**0.88**	**0.88**	**0.84**	**0.84**
Total P	0.67	0.76	0.62	0.65	0.60	0.60
Nonphytate P	0.47	0.56	**0.42**	0.44	**0.40**	**0.40**
ME kcal/lb.	**1429**	**1429**	**1452**	**1452**	**1474**	**1474**
Dig Met	0.53	0.55	0.49	0.51	0.48	0.49
Dig Lys	**1.17**	**1.17**	**0.99**	**0.99**	**0.91**	**0.91**
Dig TSAA	**0.83**	**0.83**	**0.77**	**0.77**	**0.74**	**0.74**
Tryptophan	0.22	**0.21**	0.20	0.20	0.19	0.19
Threonine	**0.89**	**0.89**	**0.78**	**0.78**	**0.71**	**0.71**
Arginine	**1.36**	**1.36**	**1.22**	**1.22**	**1.12**	**1.12**

1. Values in bold are at minimum specified level

Table 6. Proximate Analysis results for the test diets

Sample ID.	Dry Matter	Protein	Ash	Fat
	%	%	%	%
Starter				
ProPlus 57 diet	90.8	24.3	5.40	4.11
MBM50C diet	91.0	23.9	5.17	5.24
MBM50V diet	91.2	25.1	5.18	5.26
MBM50V diet	90.9	24.7	4.55	5.44
Grower				
ProPlus 57 diet	90.5	21.0	5.05	5.21
MBM 50 diet	90.7	22.1	4.89	6.20
MBM 45 diet	90.5	21.5	4.45	5.61
MBM 55 diet	91.1	21.8	4.52	6.05
Finisher				
ProPlus 57 diet	90.9	19.4	4.82	6.01
MBM 50 diet	90.6	20.5	5.03	5.42
MBM 45 diet	90.7	20.5	4.43	6.27
MBM 55 diet	90.5	21.0	4.53	6.57

Table 7. Impact of feeding diets with different sources of Animal Protein on the average live weights of male broilers grown to 49 days of age

Treatment	Live Weight at Day 0 (g/bird)	Live Weight at Day 14 (kg/bird)	Live Weight at Day 28 (kg/bird)	Live Weight at Day49[1] (kg/bird)
ProPlus 57	45.050 ± 0.178	0.430 ± 0.004	1.654 ± 0.009	3.805^{a} ± 0.024
MBM50C	44.600 ± 0.183	0.433 ± 0.007	1.650 ± 0.019	3.793^{a} ± 0.031
MBM50V	44.850 ± 0.183	0.431 ± 0.004	1.628 ± 0.007	3.724^{b} ± 0.019
MBM50V (MBM45)	44.817 ± 0.142	0.426 ± 0.004	1.611 ± 0.008	3.721^{b} ± .0154
P Value	0.3031	0.7876	0.1127	0.0142

1. Values within a column not sharing a common superscript differ (P < 0.05)

Table 8. Impact of feeding diets with different sources of animal protein on the adjusted feed conversion[1] of male broilers grown to 49 days of age (g:g)

Treatment	Feed: Gain D0-14[2]	Feed: Gain D14-28	Feed: Gain D0-28	Feed: Gain D0-49	Feed: Gain D28-49
ProPlus 57	$1.348^{ab} \pm 0.013$	$1.529^{b} \pm 0.006$	$1.482^{b} \pm 0.004$	1.709 ± 0.008	1.894 ± 0.018
MBM50C	$1.332^{b} \pm 0.012$	$1.520^{b} \pm 0.006$	$1.470^{b} \pm 0.007$	1.696 ± 0.004	1.879 ± 0.011
MBM50V	$1.324^{b} \pm 0.008$	$1.532^{b} \pm 0.005$	$1.480^{b} \pm 0.004$	1.695 ± 0.005	1.876 ± 0.013
MBM50V (MBM45)	$1.365^{a} \pm 0.006$	$1.552^{a} \pm 0.007$	$1.502^{a} \pm 0.006$	1.711 ± 0.007	1.875 ± 0.015
P Value	0.0397	0.0034	0.0003	0.1841	0.8480

1. Feed-to- gain ratios calculated by dividing feed consumed for the period by the group weight of the birds including dead and cull
2. Numbers in columns with different letter superscripts are statistically different ($P<0.05$)

Table 9. Impact of feeding diets with different sources of animal protein on the average feed intake of male broilers grown to 49 days of age

Treatment	Feed Intake D0-14 (kg/bird)	Feed Intake D14-28 (kg/bird)	Feed Intake D0-28 (kg/bird)	Feed Intake D0-49[1] (kg/bird)	Feed Intake D28-49 (kg/bird)
ProPlus57	0.518 ± 0.004	1.870 ± 0.012	2.384 ± 0.014	6.423^{a} ± 0.031	4.070^{a} ± 0.032
MBM50C	0.517 ± 0.006	1.850 ± 0.015	2.359 ± 0.020	6.357^{ab} ± 0.045	4.027^{ab} ± 0.035
MBM50V	0.511 ± 0.004	1.833 ± 0.008	2.343 ± 0.011	6.235^{c} ± 0.028	3.930^{c} ± 0.028
MBM50V (MBM45)	0.520 ± 0.005	1.839 ± 0.010	2.353 ± 0.014	6.289^{bc} ± 0.024	3.955^{bc} ± 0.018
P Value	0.5862	0.1648	0.3365	0.0020	0.0035

1. Values within a column not sharing a common superscript differ ($P < 0.05$)

Table 10. Impact of feeding diets with different sources of animal protein on the average weight gain of male broilers grown to 49 days of age

Treatment	Weight Gain D0-14 (kg/bird)	Weight Gain D14-28[1] (kg/bird)	Weight Gain D0-28 (kg/bird)	Weight Gain D0-49 (kg/bird)	Weight Gain D28-49 (kg/bird)
ProPlus 57	0.385 ± 0.004	$1.224^{\mathbf{a}}$ ± 0.008	1.609 ± 0.009	$3.760^{\mathbf{a}}$ ± 0.024	2.151 ± 0.024
MBM50C	0.389 ± 0.007	$1.217^{\mathbf{a}}$ ± 0.013	1.606 ± 0.019	$3.749^{\mathbf{a}}$ ± 0.031	2.143 ± 0.020
MBM50V	0.386 ± 0.003	$1.197^{\mathbf{ab}}$ ± 0.006	1.583 ± 0.007	$3.678^{\mathbf{b}}$ ± 0.019	2.096 ± 0.020
MBM50V (MBM45)	0.381 ± 0.004	$1.185^{\mathbf{b}}$ ± 0.009	1.566 ± 0.012	$3.677^{\mathbf{b}}$ ± 0.015	2.110 ± 0.017
P Value	0.7724	0.0344	0.1128	0.0124	0.1027

1. Values within a column not sharing a common superscript differ ($P < 0.05$)

Table 11. Impact of feeding diets with different sources of animal protein on the percent livability of male broilers grown to 49 days of age

Treatment	Livability D0-14[1] (% remaining)	Livability D0-28 (% remaining)	Livability D0-49 (% remaining)
ProPlus 57	$98.33^{a} \pm 0.59$	97.33 ± 0.57	93.00 ± 1.40
MBM50C	$96.33^{b} \pm 0.77$	95.00 ± 1.00	90.33 ± 1.81
MBM50V	$99.33^{a} \pm 0.45$	98.00 ± 0.78	94.00 ± 1.87
MBM50V (MBM45)	$97.67^{ab} \pm 0.83$	96.67 ± 0.83	93.00 ± 1.40
P Value	0.0119	0.0537	0.4860

1. Values within a column not sharing a common superscript differ ($P < 0.05$)

Table 12. Impact of feeding different animal protein sources on the selection weight for processing and carcass yield of 50 day old male broilers

Treatment	Day 50 Live Slaughter Weight	Pre-chill WOG Weight[1]	Post Chill WOG Weight[2]
	Kg/bird		
ProPlus 57	3.996 ± 0.03	2.978 ± 0.03	3.010 ± 0.03
MBM50C	3.947 ± 0.04	2.921 ± 0.03	2.950 ± 0.03
MBM50V	3.909 ± 0.03	2.894 ± 0.03	2.923 ± 0.02
MBM50V (MBM45)	3.893 ± 0.03	2.912 ± 0.02	2.943 ± 0.02
P-Value	0.1098	0.1530	0.1382

1. WOG-Carcass without giblets
2. Weight of carcass without giblets after a 2 hour chill period

Table 13. Impact of feeding different animal by-products on the absolute weight of parts of 50 day old male broilers

Treatment	Breast	Tenders	Wings	Legs (Thigh and drumstick)	Skeletal[1] And Skin
	Grams				
ProPlus 57	817.9 ± 12.7	159.8 ± 1.9	294.0 ± 2.6	934.3 ± 14.4	790.90$^{\mathbf{a}}$ ± 7.5
MBM50C	806.8 ± 11.3	154.4 ± 2.5	288.1 ± 2.3	915.5 ± 12.5	773.95$^{\mathbf{ab}}$ ± 7.4
MBM50V	795.4 ± 13.6	155.3 ± 1.6	287.0 ± 2.3	915.5 ± 6.2	760.43$^{\mathbf{b}}$ ± 6.9
MBM50V (MBM45)	803.2 ± 10.8	152.4 ± 2.5	285.3 ± 2.1	921.9 ± 8.9	766.9$^{\mathbf{b}}$ ± 6.6
P-Value	0.6156	0.0917	0.0809	0.5680	0.0352

1. Means in column with different letter superscripts are significantly different (P<0.05)

Table 14. Impact of feeding different animal by-products on the percent parts yield of 50 day old male broilers

Treatment	Breast[1]	Tenders[1]	Wings[1]	Legs[1]	Carcass Yield[2]
	%				
ProPlus 57	27.14 ± 0.23	5.31 ± 0.06	9.77 ± 0.03	31.14 ± 0.26	75.30 ± 0.15
MBM50C	27.31 ± 0.24	5.24 ± 0.24	9.78 ± 0.04	31.06 ± 0.21	74.96 ± 0.15
MBM50V	27.17 ± 0.28	5.32 ± 0.05	9.83 ± 0.04	31.32 ± 0.13	75.28 ± 0.21
MBM50V (MBM45)	27.24 ± 0.19	5.18 ± 0.06	9.71 ± 0.06	31.45 ± 0.23	75.59 ± 0.15
P-Value	0.9502	0.1888	0.4865	0.5168	0.0909

1. Percent parts is determined by dividing the absolute weight of the part by the pre-chill carcass without giblets and multiplying by 100
2. Carcass yield is determined by dividing the weight of the pre-chill carcass by the slaughter weight and multiplying by 100

Table 15. Cost of feed each treatment and the resulting diet costs per kilogram of meat

Treatment Name	0-14 days feed in kg	14-28 days feed in kg	28-49 days feed in kg	TOTAL feed in kg
ProPlus 57 cost/kg	0.518 $0.1886	1.87 $0.6632	4.07 $1.4514	6.4230 $2.3032
MBM50C cost/kg	0.517 $0.1906	1.85 $0.6549	4.027 $1.4264	6.3570 $2.2719
MBM50V cost/kg	0.511 $0.1884	1.833 $0.6488	3.93 $1.3920	6.2740 $2.2293
MBM50V (MBM45) cost/kg	0.52 $0.1917	1.839 $0.6510	3.955 $1.4009	6.2890 $2.2436

Table 16. Utilizing the Georgia Dock meat prices to calculate meat values based on the mean treatment values for live weight, carcass and parts yield

Treatment	Live Weight (kg)	Wings (g)	Breast (g)	Tenders (g)	Legs (g)	Skeletal (g)	WOG Weight (kg)	WOG Dressing %	WOG Value
ProPlus 57	3.9797	294.4333	821.1000	159.5167	941.8833	788.7167	3.0057	75.53	$7.57
MBM50C	3.9339	287.1833	807.5333	155.3000	915.0000	775.7167	2.9407	74.75	$7.40
MBM50V	3.8857	287.1500	792.0167	155.4500	914.3667	760.0167	2.9090	74.86	$7.32
MBM50V (MBM45)	3.8945	285.8966	803.1525	151.7966	924.0169	767.6949	2.9326	75.30	$7.38
per kg price GA Dock (5/11/15)		$3.685	$4.488	$4.763	$1.078	$0.11	$2.517		

Table 17. The economic value of feeding a consistent quality MBM versus variable quality MBM for 49 day old broilers

Treatment	Live Weight (kg)	Parts Value	Feed Cost	Gross Margin
ProPlus 57	3.9797	$6.6320	$2.3032	$4.3288
MBM50C	3.9339	$6.4939	$2.2719	$4.2220
MBM50V	3.8857	$6.4224	$2.2293	$4.1931
MBM50V (MBM45)	3.8945	$6.4616	$2.2436	$4.2180

UNIVERSITY OF ARKANSAS

Office of Research Compliance

MEMORANDUM

TO: Dr. Susan Watkins

FROM: Craig N. Coon, Chairman
Institutional Animal Care and Use Committee

DATE: June 6, 2014

SUBJECT: IACUC APPROVAL
Expiration date 7-1-2017

The Institutional Animal Care and Use Committee (IACUC) has APPROVED your protocol 14051: "EVALUATION OF METHODS USED TO IMPROVE THE GROWTH EFFICIENCY AND CARCASS CHARACTERISTICS OF MEAT BIRDS".

In granting its approval, the IACUC has approved only the information provided. Should there be any further changes to the protocol during the research, please notify the IACUC in writing(via the Modification form) prior to initiating the changes. If the study period is expected to extend beyond July 1, 2017 you must submit a new protocol approval. By policy the IACUC cannot approve a study for more than 3 years at a time.

The IACUC appreciates your cooperation in complying with University and Federal guidelines involving animal subjects.

CNC/aem

cc: Animal Welfare Veterinarian

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Overall Conclusions

The use of meat and bone meal as a feed additive will continually be of use in the poultry industry. The variability of the MBM can make it hard for the industry to use it as a reliable feed additive, but with a reliable source as ProPlus 57 the industry could easily feed MBM. The high digestibility of the MBM makes the product a great feed additive in the starter phase for easy digestibility for the chicks.

Overall the variability of the MBM can impact the performance of the broiler in the long term. The ProPlus 57 as a consistent MBM product can benefit the broiler in performance. Though it cost more, the more weight produced in the live weight can over turn the cost initially to allow for an overall benefit. Thus, MBM without the variability can benefit the poultry industry, until the consumers no longer allow the use of animal products in the poultry feed.