ABSTRACT

LENFESTEY, BRIDGET ANN. An evaluation of the feeding value of Prolina soybean meal in male broiler chicken diets by altering dietary protein, amino acids, and metabolizable energy. (Under the direction of John Brake).

The purpose of this research was to evaluate Prolina, a soybean cultivar developed through traditional plant breeding, as a potential feedstuff in male broiler chicken diets. Prolina soybeans were selected to possess relatively higher oil and protein while maintaining agronomic yields to improve the potential profitability of the soybean grower.

Since a large portion of the value of the soybean lies in the soybean meal used as a primary protein source in poultry and other livestock diets, six experiments were designed to investigate the effects of Prolina soybean meal when substituted for commercially available soybean meals in broiler diets. Two batches of Prolina soybeans and commercial variety soybeans were grown and processed into soybean meals. Several laboratory analyses were performed on the soybean meal samples to estimate available nutrient content such as percentage amino acids and metabolizable energy. Various strains and crosses of male broilers in both battery cages and floor pens were utilized. The response of the broilers to the dietary treatments containing the different soybean meals were generally measured by body weight, feed efficiency, and livability.

Although the experiments were able to establish that broilers could respond to increased dietary crude protein and metabolizable energy with increased body weight and improved feed efficiency, it was difficult to differentiate this effect among the soybean meal sources. However, it was observed that when dietary metabolizable energy was limiting in a diet that was formulated to be deficient in crude protein, Prolina soybean meal fed broilers had higher body weight as compared to those fed the commercial

variety soybean meals. In the final experiment, Prolina soybean meal fed broilers had the best overall performance (measured using the European Efficiency Factor) compared to birds fed commercial variety soybean meal under heat stress conditions. Supplementation of amino acids to the diet did not directly improve broiler performance, however, it was shown that birds fed diets supplemented with L-threonine had improved livability under heat stress conditions.

The six experiments conducted established that Prolina soybean meal could be substituted for commercial variety soybean meals without any decrease in broiler performance. Positive results for Prolina soybean meal were found when dietary crude protein and metabolizable energy were limiting or during heat stress conditions. Therefore, Prolina soybean meal may have an increased value in areas where these circumstances may exist.

AN EVALUATION OF THE FEEDING VALUE OF PROLINA SOYBEAN MEAL IN MALE BROILER CHICKEN DIETS BY ALTERING DIETARY PROTEIN, AMINO ACIDS, AND METABOLIZABLE ENERGY

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To my parents, Marianne and Tom, for teaching me to look at life without limitations and for providing the means for me to follow my dreams.

To Rob, for holding my hand in the frustration and lovingly guiding me to our future.

To Dr. John Brake, for sharing the knowledge and the patience.

To Susan, for making it fun.

BIOGRAPHY

Bridget Ann Lenfestey, the eldest daughter of Thomas and Marianne Lenfestey was born in Harper Woods, Michigan. Bridget completed her primary education in Sanford, North Carolina and graduated from Rochester Adams High School in Rochester, Michigan in 1994. She began her college career at Oakland University in Auburn Hills, Michigan where she pursued a Bachelor of Science degree in biology before transferring to North Carolina State University. She graduated with a Bachelor of Science in Poultry Science from North Carolina State University in 1999.

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LIST OF ABBREVIATIONS

AdjFCR	Mortality adjusted feed conversion ratio = BW of birds / (feed consumed by birds to age + BW of dead birds)
AR	Arkansas
BBI	Better Bean Initiative
BTU	British Thermal Units
BW	Body Weight
cm	Centimeter
CP	Crude protein
d	Day(s)
EEF	European efficiency factor
FCR	Feed conversion ratio
FSY	Feather-sexable yield strain
g	Gram
h	Hour
HiY	High yield
HVAC	Heating, ventilation and air conditioning
IL	Illinois
kcal	Kilocalorie
kg	Kilogram
KOH	Potassium hydroxide
m	Meter

ME	Metabolizable energy
mg	Milligram
MO	Montana
NC	North Carolina
NCSU	North Carolina State University
NIR	Near Infrared Spectroscopy
NRC	National Research Council
pH	Logarithmic scale representation of percentage acid (Hydrogen ions) in a solution
PROLINA	Soybean meal produced from Prolina cultivar beans and added to experimental diets.
rpm	Revolutions per minute
s	Second(s)
SAA	Sulfur amino acids (methionine and cystine)
SBM	Soybean meal produced from standard soybeans (G*lycine max*.) typically used in industry and added to experimental diets.
SBM+HULLS	Soybean meal produced from standard soybeans (G*lycine max*.) with additional 3% soybean hulls and added to experimental diets.
SBM+SF	Soybean meal produced from standard soybeans (G*lycine max*.) with additional 3% Solka Floc (SF) and added to experimental diets.
SE	Standard error
SF	Solka Floc, a powdered cellulose produced by Fibre Sales and Development Corp. Checkerboard Square, St. Louis, MO 63164.
THR	The amino acid L-threonine

LIST OF ABBREVIATIONS (continued)

TMEn	True metabolizable energy, corrected for nitrogen retention
ug	Microgram
USA	United States of America
USB	United Soybean Board
100-NRC	Experimental diet that included 100% of recommended NRC minimums for the amino acids lysine, methionine, and methionine + cystine
110-NRC	Experimental diet that included 110% of recommended NRC minimums for the amino acids lysine, methionine, and methionine + cystine
115-NRC	An equal blend (1:1) of the 100-NRC and 130-NRC diets.
130-NRC	Experimental diet that included 130% of recommended NRC minimums for the amino acids lysine, methionine, and methionine + cystine
85-NRC	Experimental diet that included 85% of recommended NRC minimums for the amino acids lysine, methionine, and methionine + cystine
95-NRC	Experimental diet that included 95% of recommended NRC minimums for the amino acids lysine, methionine, and methionine + cystine

CHAPTER 1

Review of Literature

Commercial Broiler Chickens. Numerous studies have established that the remarkable growth, feed conversion, and carcass composition of modern strains of commercial broilers was the result of more than 50 years of relentless genetic selection via classical population genetics. Approximately 85 percent of the improvement in these traits was attributed to genetic selection and breeding efforts and about 15 percent to changes in nutrition and management of these broilers (Sherwood 1997; Havenstein et al., 1994). Unfortunately, these advancements have not been without negative impacts on traits such as boiler livability and immune competence (Havenstein et al., 1994; Qureshi et al., 1994).

Broiler Nutrition. In many respects, broiler nutrition has struggled to maintain pace with genetic changes in these birds. To achieve maximum productivity and efficiency of these modern broiler strains, nutrition must be able to satisfy their demands. Nutrition and diet have been demonstrated to be among the easiest environmental elements of the broiler to control (Havenstein et al., 1994). Thus, the challenge for the poultry nutritionist has been to use nutrition as a tool to allow modern commercial broiler strains to reach their full genetic potential with respect to growth, feed conversion, carcass meat yield, livability and health and minimal negative environmental impacts.

National Research Council. The nutritional requirements of commercial strains of broilers have been subjected to exhaustive study over the years. The minimum requirements have been summarized by the National Research Council (NRC) on a periodic basis (NRC, 1971;

1977; 1984; 1994). These publications have provided a guide to the minimum nutritional requirements of commercial broilers that support normal physiological functions and prevent nutritional deficiencies in the birds. These recommendations were defined from numerous animal studies that were evaluated by a council of experts.

Dietary Protein. Historically, the NRC publications have not suggested a substantial increase in the minimum nutritional requirements for broilers over the years. It can, however, be assumed that with the many years of genetic selection with relatively high (≥ 25%) crude protein (CP) diets (Personal communication, Jim McKay of Ross Breeders, Ltd), the modern broiler has developed the ability to respond to CP levels in excess of those minimums stated most recently by the NRC (1994). Research has shown that broilers can respond to increased dietary CP with improved body weight (BW) and feed conversion (FCR) (Ferguson et al., 1998; Prak, 1999). Ferguson et al. (1998) also stated that the "current practice is to supply protein somewhat in excess of accepted requirements."

Amino Acids. Dietary protein requirements can be more narrowly defined with finely tuned methodology in terms of specific amino acids. Birds develop their body protein from 20 amino acids. Nine of these amino acids have been classified as essential (requiring an exogenous source) and include arginine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine. Three additional amino acids, histidine, glycine and proline, are synthesized by the bird in very small amounts. The other amino acids have been classified as non-essential amino acids because birds can synthesize enough of these to support normal physiological functions. Therefore, it has been shown that diet must supply these essential amino acids for proper growth and performance (Klasing, 1998).

Limiting Amino Acids. The amino acids that have been defined to be of most importance in a corn-soy based broiler diet were methionine and cystine, lysine, threonine, and tryptophan (NRC, 1994; Fernandez et al., 1994). These amino acids have been shown to be important due to their relative deficiencies in a corn-soy diet relative to what has been shown to be required for maximum performance. Such deficiencies can limit growth, feed conversion, and carcass meat yield. To allow birds to exhibit optimum performance, it has become essential that during the course of linear feed formulation that the limiting amino acids must be balanced in an amount sufficient to meet the requirements of the bird (Kidd et al., 2000). With this in mind, Kidd et al. (2000) re-stated the well known concept that more clearly identifying the requirements for the limiting amino acids could allow for improved formulation and result in less overall CP in the diet.

Threonine. In most practical feeding conditions the third limiting amino acid has been considered to be threonine. Most grains tend to be deficient in this amino acid and have been shown to have low digestibility in most plant feedstuffs (Degussa, 2002). Threonine has been recognized as a very important element associated with the physiological functions of the bird. Threonine is a significant component of body protein, feathers (as a component of the feather as well as precursor of glycine and serine), chicken gamma globulins, and several maintenance functions such as gastrointestinal mucin production and heat stress resistance (Lemme et al., 2002). Threonine has been shown to be catabolized to serine and glycine, which are converted to pyruvate and may subsequently result in the production of glucose to be utilized for energy. Kidd et al. (2000) have theorized that a higher percentage of non-essential amino acids in the diet would increase the threonine requirement. This was due to the requirement for the amino acid glycine, which results from the catabolism of threonine and may be used by the bird to synthesize uric acid necessary for the removal of the additional nitrogen created from the degradation of excess non-essential amino acids.

Amino Acid Balance. Baker and Chung (1992) and Baker (1997) suggested that dietary CP must be described in terms of individual amino acids and detailed an “ideal” amino acid balance that was required for broilers to obtain maximum performance. The ideal protein concept has typically used the amino acid lysine as the reference and has expressed the other essential amino acids as a percentage relative to lysine. Scott et al. (1997) stated that feeding the broiler a lower CP that was balanced for amino acids could improve overall bird health as compared to using high levels of CP with no regard to amino acid balance. Klasing (1998) used the example: “A diet with ideal balance meets requirements of young growing birds at 18%, but a poor balance requires 25%.”

Amino Acid Excesses and Deficiencies. Protein has long been accepted as essential to the broiler diet; however, Kidd et al. (2000) stated that dietary CP in excess could have negative effects on broiler performance. Also, amino acids that were not balanced decreased bird growth and feed conversion.

Klasing (1998) identified the effects of a severe amino acid deficiency in broilers as slow growth rate and decreased feed intake. A moderate amino acid deficiency can be identified by decreased feed intake and disproportional deposition of adipose tissue relative to skeletal muscle in the growing bird. A slightly marginal deficiency can be seen as an increase in adipose tissue without a decrease in BW as often observed in more severe deficiencies. This could be compensated for by the bird with increased feed intake but this could result in excess energy intake.

Amino Acid Digestibility. According to Klasing (1998) measurement of the digestibility of a feedstuff was essential to "define efficiency of utilization of nutrients, classify the quality of the food, and formulate diets." He described efficiency as measuring "size reduction, enzymatic hydrolysis, rate of passage, and endogenous losses of the nutrient." For a given feedstuff, Klasing stated that digestibility was "determined by factors inherent in chemical and structural make-up and by the digestive physiology of the bird." Therefore, when evaluating a feedstuff for feeding value in broiler diets, determination of the amino acid digestibility would be necessary.

Synthetic and Natural Amino Acids. One concern of the poultry industry has been the environmental impact of excess fecal nitrogen caused by excess CP in the diet. According to Kidd and Kerr (1996), the availability of synthetic amino acids, especially methionine and lysine, have allowed poultry nutritionist to decrease the overall CP of the broiler diet. However, they pointed out that as the CP was decreased, it was important to match the amino acid profile to the needs of the broiler. The availability of synthetic versions of the other limiting amino acids, such as threonine, has allowed nutritionists to formulate a more ideal balance on a lower overall CP. Crystalline L-threonine, produced by several feed additive companies, was created through a bacterial fermentation process. This synthetic amino acid has been generally marketed as a powder with a purity not less than 98.5% on a dry matter basis, 72 % CP, and 3.47 kcal ME/g. Synthetic amino acids such as this provide an important tool to broiler nutritionists. In an experiment by Kidd et al. (1997) broilers were fed seven graded levels of dietary threonine in the form of crystalline L-threonine. Sand was used as filler for the diets without supplementation. It was found that significant improvement in broiler BW and feed efficiency could be detected when threonine was 0.65% of the diet. Optimization of breast meat yield occurred when threonine level was 0.75% of the diet. Kidd et al. (1997) demonstrated that the optimum threonine level depended upon the parameters being measured.

Threonine and Heat Stress. Kidd et al. (2000) described the role that threonine has for broilers under heat stress conditions. He stated, "amino acids balance may be most crucial for broilers reared at high temperatures." His laboratory has conducted several experiments that demonstrated that when the broiler was under heat stress conditions the dietary threonine concentration was 111% and 105% of the NRC recommendations from 0 to 21 d and 22 to 42 d, respectively.

Energy. Energy was defined by the NRC (1994) not as a nutrient, but as a "property of energy-yielding nutrients when they are oxidized during metabolism." Other definitions listed by the NRC (1994) for energy calculations have been detailed in Table1.1.

Table 1.1. Dietary energy calculations as defined by the NRC (1994).

Type of Energy	Definition
Gross Energy (E)	The energy released as heat when a substance is completely oxidized.
Apparent digestible energy (DE)	The gross energy of the feed consumed minus the gross energy of the feces. (Since birds excrete urine and feces together, this would not be a useful measure for poultry.)
Apparent metabolizable energy (ME)	The gross energy of the feed consumed by the bird minus the gross energy contained in the feces, urine, and gaseous products of digestion. (Typical the measure of energy in poultry feeds.)
True metabolizable energy (TME)	The gross energy of the feed consumed minus the gross energy of the excreta of feed origin. A correction for nitrogen may be applied (TMEn). (The NRC (1994) stated that on an *ad libitum* fed basis, the MEn and TMEn measured values were typically very similar for poultry.)

Using the values obtained from the proximate analyses of a feedstuff sample, a prediction equation can be used to approximate the energy values of the sample. To approximate the MEn of a sample such as soybean meal the NRC (1994) suggested the use of the equation from Janssen (1989):

$$\text{MEn} = (36.63 \times \text{CP}) + (77.96 \times \text{EE}) + (19.87 \times \text{NFE})$$

Where EE = percentage ether extract and NFE =percentage nitrogen free extract.

Proximate Analyses of Feedstuffs. Laboratory analyses typically conducted on feedstuffs, such as the group of proximate analyses, could provide information helpful to the prediction of the nutritional value of a feedstuff. Perry et al. (2003) described the typical processes used for the analyses of percentage moisture, CP, crude fat, crude fiber and ash. Analytical processes have been outlined in Table 1.2.

Soybean Background Information. According to Connel (http://www.nmsu.edu, 2001), soybeans have been described as one of the most versatile seeds cultivated today. Missouri Farm Facts called the soybean (*Glycine max*) the 'miracle crop.' Soybeans have been thought to constitute the world's largest source of protein and oil and have been shown to be the only vegetable to contain eight essential amino acids. In fact, a bushel of soybeans has yielded 48 pounds of protein-rich meal and 11 pounds of oil (Missouri Farm Facts, http://agebb.Missouri.edu). Although soybeans originated in China, the United States has become the largest producer in the world. Soybeans have become the second largest cash crop in the U.S.A.with every other row of soybeans planted going to export. The United

Table 1.2. Analytical processes for percentage moisture, crude protein, crude fat, and crude fiber.

Analysis	Process	Calculation
Percentage moisture	Sample (10g) dried at 135 C for 2 h.	= ((wt. of sample after drying)/(wt. of sample before drying)) x 100
Percentage CP	Determine ammoniacal nitrogen (N) by digesting sample in concentrated sulfuric acid in the presence of potassium or sodium sulfate plus a catalyst to convert all ammoniacal N to ammonium sulfur. Add an excess of concentrated sodium hydroxide to make the solution strongly alkaline causing all ammoniacal N to form ammonium hydroxide. Add water and distilled ammonia into a known quantity of standard acid solution. Determine by titration with standard alkali the amount of acid neutralized by the ammonia formed from the N in the feedstuff sample. Note that CP was different than true protein because it contained nitrogen from free amino acids, enzymes, vitamins, urea, biuret, ammonia, etc…Note: The percentages of individual amino acids may be determined by an HPLC method.	= ((N x 6.25) / (wt. of sample)) x 100
Percentage crude fat	Weigh out small sample extraction. Dry the sample. Extract with ether and evaporate the ether from the extract. Weigh the remainder.	=(wt. of crude fat) / (wt. of sample used) x100
Percentage crude fiber and ash	Extract with ether. Boil in dilute sulfuric acid (1.25 %) for 30 minutes and filter. Boil in dilute sodium hydroxide (1.25%) for 30 minutes and filter. Dry residue and weigh to obtain crude fiber and ash. Ash sample and subtract percentage ash This fiber sample represents only part of the hemicelluloses and lignin, as the rest disappears as protein and starch components.	% Crude fiber = ((wt. of crude fiber) / (wt. of original sample)) x 100 % Ash = ((wt. of ash) / (wt. of original sample)) x 100.

Soybean board reported that soybeans constituted 52% of the world's oilseed production and 73.8 million acres of soybeans were planted (USB Soy Stats, 2000). Also, the U.S. soybeans provided 82% of edible fats and oils human and animal diets.

Soybeans have become common ingredients in various industrial materials, human food derived from either soy protein or soy oil, and animal feeds in the form of soybean meal. Thus, the continuing demand for this crop has been driven, primarily, by the numerous human and animal food uses.

Soybean Meal. The soybean has been generally processed for protein or oil extraction. These valuable parts of the soybean then enter the human food industry. However, when the oil was extracted from the whole bean, the remaining by-product became soybean meal. It was reported by the United Soybean Board (2000) that this "by-product" used in animal feeds represented approximately 60% of the value of the whole bean. Soybean meal has become a major protein component in swine and poultry livestock feed, especially in the USA. Astonishingly, livestock consume nearly 80% of the world's soybean meal production. Poultry, primarily broilers, consume nearly half of this (USB Soy Stats, 2000). Soybean meal has become particularly useful in formulation of broiler diets due to the nearly ideal amino acid balance that results when combined with generally abundant and economical corn (Baker, 1997). It has also been demonstrated that the protein found in soybean meal has the digestibility of animal proteins. Mature soybeans have been characterized to have approximately 40% CP, 21% oil, and 5% ash (Burton, 1997). Soybean meal has become the simplest form of soy protein and typically contains 44-48% CP, depending on the fibrous hull content (www.centralsoya.com).

Soybean Processing. Soybeans and soybean meal must be processed (toasted) to reduce the anti-nutritional factors such as: trypsin inhibitors, urease, lectins, goitrogens, saponins, indigestible and fermentable sugars, stachyose, raffinose, sucrose, pathogenic organisms, and soy antigens that can negatively affect the performance of young broiler chickens. Garlich (1988) discussed the importance of toasting the beans to allow optimum digestion of the proteins and absorption of the amino acids.

Industry Processing. Typical industry processing of large batches of soybeans to soybean meal include a multi-step system to provide a toasted soybean meal that can be used in the poultry feed industry. The typical steps for soybean meal processing are outlined below in Figure 1.1.

Laboratory Processing. For smaller test or pilot batches of beans, several methods exist to process soybeans and ensure proper destruction of the anti-nutritional factors that may reduce the performance of young broilers. The beans can be boiled (30 min) or autoclaved. Infrared radiation with a wavelength of 1.8-3.4 microns can also be used to heat the beans via radiation. Roasting (110 -170 C) and extrusion (138 -150 C) are the most common methods and involve heat and heat with pressure, respectively (Loon, 2002). Soybeans contain oligosaccharides (raffinose, stachyose and verascose), which cannot be

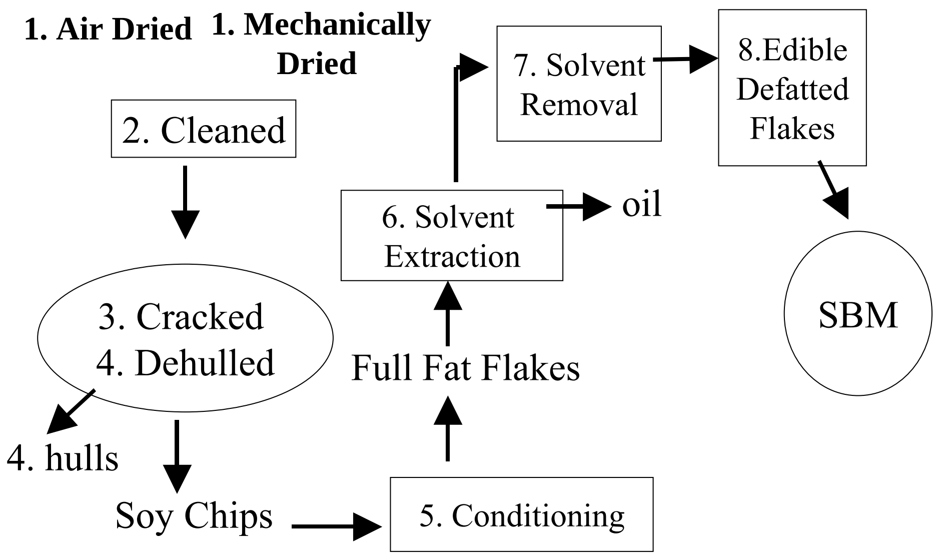

Figure 1.1. Steps to process soybeans into oil and soybean meal.
1. Soybeans are dried either mechanically or by air to approximately 9.5 % moisture. 2. They are cleaned to remove foreign material. 3. The whole beans are tempered to loosen hulls that surround the bean. 4. Beans are cracked into 8 to 16 pieces as they pass through corrugated rolls. The soybean hulls, which are approximately 8% of the bean, are removed by aspiration. 5. The remaining soybean meat is heated to 74 C. The 'meat' is then passed through a smooth roller where the meat is flaked and oil cells ruptured. 6. The resulting flakes are washed with hexane, which forms a complex with the soybean's oil. 7. The hexane-oil mixture is removed. The desolventor-toaster then removes any hexane residues in the bean meal and denatures proteins such as trypsin inhibitors and improves the nutrient availability of the meal. 8. The oil extracted bean meal then enters the dryer-cooler units and is dried to approximately 13 to 14 percent moisture. The meal is then screened and ground by the hammer mill to uniform size and is prepared for shipment or storage.

digested by poultry due to the lack of the alpha-galactosidase enzyme. These constituents can be extracted with ethanol if necessary (Soybean Meal Infosource, 2000). Values from 3.7 to 4.5 mg/g have generally been determined to be acceptable (Loon, 2002).

Soybean Meal Analyses. Loon (2002) described several ways to evaluate the destruction of anti-nutritional factors. He suggested that the use of a casein-agar column, incubated for two hours, and then marked against untreated soybeans was the least tedious method. The urease test could also be a marker for destruction of trypsin inhibitors. Urease has been shown to be an enzyme used by the soybean plant during the seed formation and germination processes, but can be denatured by cooking. Enzyme activity may be assayed by measuring the reduction of urease activity post-processing and measuring the pH change as urease enzymes convert urea to ammonia. Garlich (1988) stated that it has been determined through animal assays that a properly processed sample of soybean meal will give a 0.05 to 0.20 increase in pH units (unprocessed meal has a pH of ~2.0).

Since processing method and duration affect chemical and physical properties of soybean meal, a protein solubility test has also been used to diagnose over-processing. These test results have been positively correlated with growth responses of poultry (Garlich, 1988; Loon, 2002). This test has been generally conducted by dissolving soy proteins in 2% potassium hydroxide (KOH) solution. The nitrogen was dissolved then the supernatant can be determined by the Kjeldahl method. Protein solubility of 80 to 85% has been shown to be desirable to for young broilers.

Soybean Breeding. The soybean is of significant value to the livestock industry in its form as soybean meal. However, a number of competing sources of soybean meal, as well as alternative protein sources, have developed on a worldwide basis. Furthermore, competing sources of oils for industrial and food applications have been developed. Because of this competition, efforts have been undertaken to enhance the "value-added" oil and protein traits of soybeans by modification of fatty acid and amino acid profiles so as to improve the competitive position of USA soybean growers. However, protein and oil traits have been shown to be negatively correlated (Burton, 1997; Li and Burton, 2002). Other areas targeted for improvement have included increased lysine, improved carbohydrate profile, and lower phytate phosphorus (Bajjalieh, 2002).

The United Soybean Board's Better Bean Initiative. There has been an interest in improving the amino acid composition of basic grains such as soybeans, to naturally supply certain deficient essential amino acids and hence decrease the use of their synthetically produced counterparts and more closely mimic the required "ideal" profiles of amino acids for livestock. The recent public efforts in this direction have been coordinated within the United Soybean Board's "Better Bean Initiative (BBI)." The stated mission of the BBI has been to accelerate the development and availability of soybean seed with enhanced compositional traits that will better position soybeans to meet the needs of oil and protein end users (BBI, 2000). Bajjalieh (2002) pointed out that value could be added only if it covered the additional costs of research and development, loss of yield and provide an incentive for use.

Soybean Protein. As stated in the BBI (USB, 2000), efforts to increase amino acids such as methionine and cystine via increasing protein storage subunits in the seeds must be part of the breeding program (Burton, 1997). Yagasaki et al. (1997) characterized the subunits of interest for increased protein in the soybean as glycinin (11S structure) and β-conglycinin (7S). Glycinin has been shown to be a major protein storage subunit in the bean making up about 35% of total seed protein. This subunit has provided the isolated soy protein used by the human food industry in tofu production. Tofu from glycinin has been found to be firmer than that from the second largest storage subunit, β-conglycinin. When the glycinin has been altered by soybean breeding, differences in protein-gel formation and firmness of the tofu can be detected. Therefore, examination of the 11S to 7S ratio can suggest differences in storage protein in the bean (Yagasaki et al., 1997).

It is unclear as to whether increasing the protein content of the soybean would alter the amino acid content (balance) of the bean. Nelson et al. (1976) reported that for eleven different soybean meals, with a large range of CP content, there were no variations in the relative content of the amino acids threonine, serine, cystine, methionine, leucine, and lysine. However, there were other variations among the remaining amino acids when reported on a dry matter basis.

Burton et al. (1997) reported that the increasing seed mass of the wild soybean germplasm (*Glycine soja*) via breeding methods could increase the seed content of glycinin (11S) storage protein. Increasing this subunit genotypically increased the protein content of the bean. A strong positive correlation between glycinin and β-conglycinin ratio and methionine and cystine content was reported. Moderate positive associations were found between the ratio and threonine. A negative correlation was found between the ratio and lysine. Burton also stated that the large amount of phenotypic diversity in protein content and composition maybe due to a different complement of genes that control expression of 11S and 7S protein between *Glycine soja* and *Glycine max*.

Protein and Energy Analyses of Soybean Meal. According to Edwards et al. (2000), comparisons of the nutrient content of soybean meal may be partially evaluated by proximate analyses. These analyses can determine dry matter, Kjeldahl nitrogen, total fat, phospholipids, and neutral detergent fiber. Edwards et al. (2000) reported that these methods could identify differences in nutrient values between various soybean meals. The processes for determination of true metabolizable energy and amino acid digestibility generally use the individually caged cecectomized Single Comb White Leghorn rooster. In this method, the feed deprived roosters are given sample of soybean meal, a subset of the roosters have food deprivation continued to produce endogenous nutrient excretion values. The sample birds then have excreta collected for 48 hours and which is then assayed to determine CP by Kjedahl nitrogen and gross energy by bomb calorimeter. Then, the amino acid concentrations of each sample are generally carried out using hydrolysis followed by ion exchange chromatography. Sulfur amino acids are determined on samples that have been pre-oxidized with performic acid prior to acid hydrolysis.

Establishing a Feeding Value. Ferguson et al. (1998) stated that “amino acid and energy requirements of broilers vary widely with newer genotypes, and it is unclear whether these requirements are truly known.” With multiple soybean cultivars being developed at present and a large part of the soybean’s value being in the soybean meal, it has become important to develop a process, or biological assay, to confirm the feeding value of the meal produced from new soybean cultivars in poultry diets as quickly, efficiently, and accurately as possible. According to Carney and Morris (2002), experimental designs should include measures that can identify differences in live performance and yield and trials must be designed to eliminate variation, especially in management and feed practices. Measurements should include BW of the birds, livability measures, feed conversion and carcass quality, as these all contribute to the final profit from the broiler.

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CHAPTER 2

A preliminary evaluation of the body weight and feed efficiency of the young male broiler in response to varying levels of protein, amino acids, and Prolina soybean meal in the diet

ABSTRACT. Previous research has suggested that broiler chickens can respond positively to dietary CP and amino acids in excess of the National Research Council (NRC, 1994) suggested minimums. As increased levels of dietary CP have an associated cost, it was important to determine the optimum levels of CP and the age at which the broiler was most sensitive. Also, it was valuable to evaluate feedstuffs that may contribute higher CP to the diet without increasing the diet cost. Experiment 2.1 was designed to delineate the effects of increasing CP level on the early growth and feed conversion ratio (FCR) of male broiler chickens. Experiment 2.2 was designed to screen for any performance effects found in broilers fed diets containing a high protein soybean meal processed from the Prolina soybean cultivar. For both experiments, broilers were placed randomly in 24 battery cages, 10 birds per pen, and grown to 28 d. For Experiment 2.1, birds were fed a common starter feed from 0 to 7 d and then fed the dietary treatments. In Experiment 2.2 birds were fed dietary treatments from placement. In both experiments, two diets were formulated and then combined in a 1:1 ratio to create a third, intermediate diet. In Experiment 2.1, dietary treatments consisted of 100, 115 and 130% of the NRC recommended levels for the amino acids lysine, methionine, and methionine + cystine and formulated with standard soybean meal as the protein source. Experiment 2.2 diets were formulated at 100% of the NRC recommendations for the lysine, methionine, and methionine + cystine. Three diets were created by direct substitution of either a commercially available soybean meal, Prolina soybean meal, or a 1:1 blend of the two diets. Bird BW and feed consumption were measured

weekly. Calculation of FCR and livability were done for weekly increments. In Experiment 2.1, there was evidence that BW and FCR were most sensitive to higher CP levels between 14 and 21 d. This suggested that young broilers could respond to dietary CP levels higher than the recommended minimums of the NRC. Experiment 2.2 demonstrated that Prolina soybean meal could be substituted for the commercially available soybean meal in the diet of a young male broiler without negative effects.

Introduction

Prolina soybeans were one of the first non-genetically modified soybean cultivars made available through the efforts of the United Soybean Board (USB) in a quantity sufficient to test in large animal feeding trials (USB, 2000). Prolina was developed as a soybean that possessed enhanced oil and protein value while maintaining reasonable agronomic values. This made the Prolina soybean potentially valuable for growers and very useful in the human and animal food industries. The oil yield had obvious value and the amino acid composition of the protein was very attractive for the production of high value specialty items such as bean curd (tofu). Therefore, the soybean meal made from Prolina could be expected to have CP content and amino acid balance altered from that found in standard, commercially available soybean meals. This amino acid balance could potentially have increased value in the animal feeding industry.

To study the animal feeding value of the cultivars like Prolina, that potentially have higher levels of CP and amino acids, it was first necessary to determine how a modern commercial strain of broiler chicken would respond to dietary levels of CP and limiting amino acids in excess of the NRC recommendations (NRC, 1994). Experiment 2.1 was a preliminary study designed to focus on the most limiting amino acids in a typical corn-soy broiler diet, lysine, methionine, and methionine + cystine (Yanming and Baker, 1993). Experiment 2.1 would show how male broiler chickens react to dietary levels of lysine, methionine, and methionine + cystine thought to be either adequate or greatly in excess of their minimum requirements. Due to the preliminary nature of this study, response to the increased percentage of lysine, methionine, and methionine + cystine relative to NRC recommendations were to be determined by BW, FCR, and livability (Ferguson et al., 1998; Prak et al., 1999).

The next feeding trial, Experiment 2.2, was the first step in establishing the value of Prolina soybean meal as a feed component in poultry diets. This preliminary feeding trial was designed to establish how male broiler chickens would respond to the presumed altered amino acid balance found in the Prolina soybean meal as compared to a commercially available soybean meal. Since it was suggested that male broiler chickens could respond to incremental increases in CP as might be presented by Prolina soybean meal, and if this protein was in a form with a suitable amino acid balance that could be fully utilized by the broiler, then a positive response to dietary CP and/or amino acid balance may be recognizable as improved BW and FCR (Ferguson et al., 1998; Prak et al., 1999). Also, since young broilers have been reported to be highly sensitive to anti-nutritional factors, such as trypsin inhibitors that can be found in soybean meal, this trial would be a tool to screen for potential detrimental effects caused by unknown components of Prolina soybean meal (Garlich, 1988).

These preliminary feeding trials, Experiment 2.1 and 2.2 were designed to obtain the additional information needed to design a series of more involved experiments that would more fully evaluate Prolina soybean meal and its value as a high protein soybean meal in broiler diets.

Experiment 2.1

Materials and Methods

Birds and Facility. Ross 508 strain broilers were sexed and individually identified with neck tags at hatch. A total of 240 male broilers were randomly distributed among 24 pens, 10 birds per pen, in two custom-designed brooding battery cages (Alternative Design, Siloam Springs, AR 72761) that were three pens wide by four pens high. Each pen measured 55 cm wide, 67 cm deep and 35 cm high. At 14 d, the birds were transferred to three custom-designed grow-out cages (Alternative Design, Siloam Springs, AR 72761) that were three pens wide by three pens high. Each pen measured 84 cm wide, 46 cm deep and 51 cm high. Treatment assignments for the grow-out pens were randomized at transfer. In addition to a warm air re-circulation system, electrical resistance heat sources were placed at each of the four levels of the brooding cages to provide uniform heat. The room was temperature controlled with a standard heating, ventilation and air conditioning system (HVAC) during both brooding and grow-out stages. There were two 1/10 horsepower circulating fans directed upwards in each room to provide additional assurance of uniform temperature distribution and de-stratification. Room temperature was maintained at 24-27 C and the supplemental heat source at each level allowed the pen temperatures to be 32 C at placement and to be decreased by 3 C weekly until 24 C was reached. Birds received 20 h of light per day, which was supplied by overhead fluorescent bulbs throughout the experiment. Birds were provided feed and water for *ad libitum* consumption using one trough feeder and two nipple drinkers per pen. Supplemental feed on a brown paper towel was placed on the wire floor of each pen from hatch to 7 d. A corn-soy mash starter feed was fed to all chicks from 0 to 7 d to allow the chicks to become accustomed to the cages, at which point 8 chicks that had adapted to the cages and did not have extreme BW were selected to remain in each pen.

Diets. A corn-soy mash starter diet was formulated to meet or exceed NRC recommended minimum levels for CP and metabolizable energy (ME) and was fed to all birds from 0 to 7 d. Dietary treatments began on the seventh day and were constituted from two basal corn-soy starter diets that were formulated at 100% (100-NRC) and 130% (130-NRC) of the NRC (NRC, 1994) recommended values for CP with emphasis on maintaining the same balance of the essential amino acids, lysine, methionine, and methionine + cystine, with a calculated basal ME of 3.05 kcal/g. A portion of these two mash feeds were then blended in equal parts using a Hobart vertical mixer (Model L-800, Hobart Manufacturing Company, Troy, OH, 45373) to create a third diet, which possessed 115% (115-NRC) of the NRC recommended levels for these essential amino acids. The three dietary treatments were then fed to the birds from 7 to 28 d of age. Samples of each finished diet were subjected to proximate analyses (Woodson-Tenent Laboratories, Goldston, NC 27252) to confirm the CP values.

Data Collection. High and low room and pen temperatures were recorded twice daily to assure proper environmental conditions. Feed consumption and BW were measured weekly on a pen basis from 7 to 28 d. Dead birds were weighed and recorded twice daily. This facilitated livability to be reported on a cumulative basis. FCR[1] was calculated on a cumulative basis (from 7 d) at weekly intervals.

[1] FCR = Total feed consumed ÷ Total BW of surviving birds.

Statistical Analysis. The experimental design consisted of three levels of dietary CP within a randomized complete block design with 24 experimental units. The three grow-out cage levels were used as the blocks but upon analysis no block effect was found. There were eight replicate pens per diet. Statistical analysis was carried out as a one-way analysis of variance using the General Linear Models procedure of SAS® institute (SAS Institute, Inc., Cary, NC 1999-2001). Error was calculated from between replicate pen variation (residual). Means were partitioned using the Duncan option. Statements of statistical significance were based upon $P \leq 0.05$ unless otherwise indicated.

Results

Diet Analyses. The percentage CP and ME values that were calculated using a linear programming feed formulation method and the results of the analyses for percentage moisture, CP, fat, fiber, and ash for the experimental diets are shown in Table 2.1. The analyzed values of the samples were found to be similar to the calculated percentage CP values. Percentage moisture and fiber were similar across the three dietary treatments. Percentage fat and ash increased with the percentage CP in the diet. Overall, the proximate analyses were in general agreement with the linear program's calculated values for the dietary treatments and the desired stepwise increase in CP was apparent.

Body Weight. Table 2.2 shows BW at 7, 14, 21, and 28 d of age. There was no statistical difference for BW among the treatment groups at 7 d, which was prior to the feeding of the experimental diets began. At 14 and 21 d the birds receiving the 115-NRC and 130-NRC dietary treatments exhibited significantly greater BW than the 100-NRC treatment. At 28 d the birds receiving the 115-NRC dietary treatment exhibited greater BW than the 100-NRC treatment with the 130-NRC treatment intermediate ($P \leq 0.10$).

Table 2.1. Analyses and compositions of dietary treatments in Experiment 2.1.[1]

Ingredient	100-NRC[2]	115-NRC[2]	130-NRC[2]
		(%)	
Corn	59.93	50.95	41.96
Soybean meal[3]	32.80	40.55	48.30
Poultry fat	2.63	3.88	5.13
Dicalcium phosphate	2.13	2.06	1.99
Limestone (calcium carbonate)	1.17	1.16	1.15
Salt (NaCl)	0.50	0.50	0.50
Trace mineral premix[4]	0.20	0.20	0.20
Vitamin premix[5]	0.05	0.05	0.05
Choline chloride (60%)	0.20	0.20	0.20
D, L-Methionine	0.22	0.29	0.35
Coccidiostat	0.07	0.07	0.07
Selenium premix[6]	0.10	0.10	0.10
Total	100.00	100.00	100.00
Calculated Analyses[7]			
Metabolizable energy, kcal/kg	3050	3050	3050
Crude protein, %	22.00	24.50	27.00
Actual Analyses[8]			
		(%)	
Crude protein	21.86	25.00	28.16
Moisture	11.40	11.18	11.18
Fat	4.43	5.49	6.78
Fiber	2.00	1.80	1.80
Ash	6.05	6.26	6.62

[1] Experimental diets were fed to birds beginning at 7 d of age.
[2] 100-NRC and 130-NRC diets were created by formulating for 100% and 130% of the NRC (1994) minimum recommendations for lysine, methionine, and methionine + cystine, respectively. Blending the 100-NRC and 130-NRC diets in a 1:1 ratio created the 115-NRC diet.
[3] Soybean meal was a standard 48% crude protein meal typically used in industry (Cargill, Raleigh, NC 27603).
[4] Supplied per kg diet: manganese 120 mg, zinc 120 mg, iron 80 mg, copper 10 mg, iodine 2.5 mg, and cobalt 1.0 mg.
[5] Supplied per kg diet: retinol 6600 IU, cholecalciferol 2000 IU, vitamin E 33 IU, vitamin B_{12} 19.8 ug, riboflavin 6.6 mg, niacin 55 mg, pantothenic acid 11 mg, vitamin K 2 mg, folic acid, 1.1 mg, thiamin 2 mg, pyridoxine 4 mg, and biotin 126 ug.
[6] Selenium premix provided 0.10 mg selenium/kg of diet.
[7] Calculated analyses were conducted with a linear programming feed formulation method.
[8] Proximate analyses performed by Woodson-Tenent Laboratories, Goldston, NC 27252.

Table 2.2. Effect of dietary crude protein level on body weight (BW), cumulative feed conversion ratio (FCR), and percentage livability of male broiler chickens at 7, 14, 21, and 28 days of age in Experiment 2.1.

	7d	14 d			21 d			28 d		
Dietary Treatment[4]	Initial BW[1]	BW	FCR[2]	Livability[3]	BW	FCR[2]	Livability[3]	BW	FCR[2]	Livability[3]
	(g)	(g)	(g:g)	(%)	(g)	(g:g)	(%)	(g)	(g:g)	(%)
100-NRC	146.2	393.0[b]	1.44	98.44	774.4[b]	1.54[a]	98.44	1221.2[x]	1.66	96.88
115-NRC	152.1	411.2[a]	1.38	100.00	814.5[a]	1.48[ab]	98.44	1273.1[y]	1.58	98.44
130-NRC	148.3	407.7[a]	1.34	100.00	800.8[a]	1.46[b]	100.00	1253.9[xy]	1.56	100.00
SE	2.4	7.9	0.04	0.74	16.6	0.03	0.74	21.4	0.04	0.74

[a,b] Means in a column with no common superscript differ significantly ($P \leq 0.05$).
[x,y] Means in a column with no common superscript approach significance ($P \leq 0.10$)
[1] Initial BW measured at 7d of age at which point feeding of the experimental diets began.
[2] FCR = feed consumed to age ÷ live BW on a cumulative basis beginning at 7 d of age.
[3] Percentage birds remaining alive at the respective ages.
[4] Represents dietary crude protein as a percentage of the NRC (1994) recommendations based upon minimum levels of the amino acids lysine, methionine, and methionine + cystine.

Feed Conversion Ratio. Cumulative FCR data calculated to 14, 21, and 28 d are shown in Table 2.2 for the chicks fed the three experimental diets. At 14 d, there were no significant differences among the dietary treatments. By 21 d, the chicks receiving the 130-NRC treatments exhibited a significantly improved FCR as compared to the 100-NRC treatments with the 115-NRC treatment intermediate. This effect was not found to be significant at 28 d.

Livability. Overall livability was excellent in this trial as shown in Table 2.2. No significant differences in livability were seen among the three dietary treatments throughout the experiment. However, it was interesting to note that no birds died in the 130-NRC dietary treatment during the trial.

Experiment 2.2

Materials and Methods

Prolina Soybean Production-Pilot Batch. A pilot plot of Prolina soybeans was grown in Northeastern North Carolina by Eure Farms using standard identity preservation procedures (Personal Communication from Myron Fountain, NC Foundation Seed Producers, Raleigh, NC 27654). After harvest, the soybeans were shipped to Texas A&M University and processed at a pilot soybean processing facility. After processing, a test of urease levels indicated improper destruction of enzyme inhibitors. The processing procedure was repeated to correct the problem. Urease, KOH, proximate analyses, amino acid content analyses and amino acid digestibility analyses were conducted on the Prolina soybean meal and a commercially available soybean meal that was grown during the same season and in the same region. This pilot batch of Prolina soybean meal was used only in Experiment 2.2.

Birds and Facility. Male broiler offspring from the cross of the Ross male x Arbor Acres FSY female were sexed and individually identified with neck tags at hatch. A total of 192 male broilers were randomly distributed among 24 battery pens, 8 chicks per pen, for brooding in custom built battery cages as described in Experiment 2.1. At 14 d, the birds were transferred to custom built grow-out cages as described in Experiment 2.1. Birds were provided feed and water for *ad libitum* consumption using one trough feeder and two nipple drinkers per pen. Supplemental feed on a brown paper towel was placed on the wire floor of each pen from hatch to 7 d.

Diets. A basal corn-soy mash starter diet was formulated with a calculated basal ME of 3.05 kcal ME/g and 100% of NRC recommended levels for the lysine, methionine, and methionine + cystine using a commercially available soybean meal as the soybean meal source (no samples of this diet were analyzed). Three dietary treatments were created by directly substituting Prolina soybean meal (PROLINA), the commercially available soybean meal grown in the same region (SBM), or an equal blend (1:1) of the two soybean meals (BLEND) by weight as the soybean meal source as shown in Table 2.3. Dietary treatments were fed from 0 to 28 d.

Data Collection. High and low room and pen temperatures were recorded twice daily to insure proper brooding and management conditions. Individual bird BW and pen feed consumption were measured weekly from 0 to 28 d. Dead birds were weighed and recorded twice daily. The FCR[2] and feed conversion ratios adjusted for mortality[3] (AdjFCR) were calculated at weekly intervals.

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[2] FCR = Total feed consumed ÷ Total BW of surviving birds.
[3] AdjFCR= Total feed consumed ÷ (BW of surviving birds + total terminal BW of birds that died).

Table 2.3. Compositions of starter diets used in Experiment 2.2.

Ingredients	Constants	PROLINA[1]	BLEND[2]	SBM[3]
		(%)		
Prolina soybean meal		35.54	17.77	…
Soybean meal		…	17.77	35.54
Corn	56.98			
Poultry fat	3.05			
Dicalcium phosphate	2.10			
Limestone (calcium carbonate)	1.17			
Salt (NaCl)	0.38			
Trace mineral premix[4]	0.20			
Vitamin premix[5]	0.05			
Choline chloride (60%)	0.20			
DL-Methionine	0.16			
Coccidiostat	0.07			
Selenium premix[6]	0.10			
Total		100.00	100.00	100.00
Calculated Analyses[7]				
Metabolizable energy, kcal/kg	3050			
Crude protein, %	22.00			

[1] Diet containing Prolina high protein experimental soybean meal (PROLINA).
[2] Diet containing PROLINA and SBM were blended in a 1:1 ratio (BLEND).
[3] Diet containing soybean meal (SBM) obtained from Cargill, Raleigh, NC 27603.
[4] Supplied per kg diet: manganese 120 mg, zinc 120 mg, iron 80 mg, copper 10 mg, iodine 2.5 mg, and cobalt 1.0 mg.
[5] Supplied per kg diet: retinol 6600 IU, cholecalciferol 2000 IU, vitamin E 33 IU, Vitamin B_{12} 19.8 ug, riboflavin 6.6 mg, niacin 55 mg, pantothenic acid 11 mg, Vitamin K 2 mg, folic acid 1.1 mg, thiamine 2 mg, pyridoxine 4 mg, and biotin 126 ug.
[6] Selenium premix provided 0.10 mg selenium/kg of the diet.
[7] Derived from the linear programming method of feed formulation.

Statistical Analysis. The experimental design consisted of three dietary treatments within a randomized complete block design with 24 experimental units. The three grow-out cage levels were used as the blocks and upon analyses, no block effects were found. There were eight replicate pens per diet. Statistical analysis was carried out using a one-way analysis of variance using the General Linear Models procedure of SAS® institute (SAS Institute, Inc., Cary, NC 1999-2001). Error was calculated from between replicate pen (residual) variation. Means were partitioned using the Duncan option. Statements of statistical significance were based upon $P \leq 0.05$ unless otherwise indicated.

Results

Prolina Soybean Processing-Pilot Batch. After initial processing of the Prolina soybeans into soybean meal, a sample was analyzed using the urease and KOH-protein solubility methods to determine if the beans had been properly processed. The urease and KOH-solubility values indicated undercooking after the primary processing. Therefore, the Prolina soybean meal was reprocessed at the same facility. As shown in Table 2.4, the results of the analyses performed on the sample of the reprocessed Prolina soybean meal present satisfactory values that ensured destruction of anti-nutritional factors without apparent damage to the soybean’s protein.

Proximate Analyses of Soybean Meal. Percentage moisture, fat, CP, crude fiber, and ash for single samples of the Prolina soybean meal and commercially available soybean meal are shown in Table 2.5. The sample of commercially available soybean meal had higher percentage moisture as compared to the Prolina soybean meal sample. The percentage fat and CP were slightly higher for the Prolina when compared to the other soybean meal sample. The percentage crude fiber and ash were similar in both soybean meal samples.

Table 2.4. Analyses of Prolina high protein soybean meal before and after reprocessing of the pilot batch used in Experiment 2.2.

Analyses[1]	Prolina Soybean Meal[2]	
	Before[3]	After[4]
Protein Solubility by KOH, %	85.93	88.99
Protein by Kjeldahl, %	51.90	52.25
pH unit increase	0.35	0.07

[1] Analyses conducted at Woodson-Tenent Laboratories, Goldston, NC 27252.
[2] Sample from the pilot batch of Prolina soybean meal.
[3] Sample analyzed after the first processing at the pilot soybean processing plant at Texas A & M University, College Station, TX 77840.
[4] Sample analyzed after the re-processing at Texas A & M University.

Table 2.5. Proximate analyses of Prolina soybean meal and commercially available soybean meal samples used in the dietary treatments for Experiment 2.2.

Proximate Analyses[1]	Prolina Soybean Meal[2]	Commercially Available Soybean Meal[2]
Moisture, %	7.23	11.88
Fat, %	2.60	1.06
Crude protein, %	51.53	49.11
Crude fiber, %	3.30	3.10
Ash, %	6.28	6.55

[1] Proximate analyses conducted by Woodson-Tenent Laboratories, Goldston, NC 27252.
[2] Sample from pilot batch of Prolina experimental high protein soybean meal.
[3] Sample of standard commercially available soybean meal (Cargill, Raleigh, NC 27603).

Amino Acid Analyses. The results of the amino acid analysis for Prolina and the commercially available soybean meal are shown in Table 2.6 and are based on a single sample of each. This analysis indicated that the amino acid profile of the Prolina soybean meal was similar to that of the other soybean meal. The percentage amino acid digestibilities, as determined by the cecectomized rooster method, are shown in Table 2.7 and are based on a single sample of each soybean meal. The results of this analysis indicated that the commercial soybean meal had a numerically higher percentage digestibility for most amino acids as compared to the Prolina sample.

Live Performance. Table 2.8 shows the BW, cumulative FCR and cumulative livability for the broilers fed diets made with the three sources of soybean meal at 0, 7, 14, 21, and 28 d. There were no differences in BW among the treatments throughout the trial. The birds fed the PROLINA treatment had a significantly improved FCR as compared to the BLEND and SBM treatments at 7 d but there were no differences observed at 14, 21 or 28 d. There were no differences found for livability of the birds receiving the different dietary treatments at any age.

Discussion

Experiment 2.1. The results of Experiment 2.1 supported the findings of Prak et al. (1999) who had concluded that the current NRC recommendations were inadequate with regards to the dietary amino acid requirements of male broiler chickens to support maximum growth and feed efficiency. This experiment also reinforced the concept that as the bird ages and consumes more feed, the level of amino acids as a percentage of the diets, may be reduced. The NRC suggested a decrease in percentage amino acids at 22 d of age. However, the broilers in Experiment 2.1 continued to show a BW response when fed the 130-NRC

Table 2.6. Amino acid analyses of Prolina soybean meal and commercially available soybean meal samples used in the dietary treatments for Experiment 2.2.

Amino Acids[1]	Prolina Soybean Meal[2]	Commercially Available Soybean Meal[3]
	(%)	
Taurine	0.05	0.03
Hydroxyproline	0.00	0.07
Aspartic Acid	5.56	5.34
Threonine	1.88	1.87
Serine	2.13	2.23
Glutamic Acid	8.96	8.66
Proline	2.52	2.35
Lanthionine	0.01	0.01
Glycine	2.02	2.00
Alanine	2.09	2.11
Cystine	0.79	0.75
Valine	2.23	2.34
Methionine	0.71	0.67
Isoleucine	2.17	2.22
Leucine	3.78	3.68
Tyrosine	1.79	1.69
Phenylalanine	2.52	2.43
Hydroxylysine	0.03	0.00
Histidine	1.29	1.29
Ornithine	0.03	0.01
Lysine	3.04	3.02
Arginine	3.54	3.54
Tryptophan	0.72	0.67

[1]Amino acid analyses performed on a single sample by the laboratory of Dr. T.P. Mawhinney, Experiment Station Chemical Laboratories, University of Missouri, Colombia, MO 65211.

[2] Sample of Prolina high protein soybean meal from the pilot batch.

[3] Sample of commercially available soybean meal (Cargill, Raleigh, NC 27603).

Table 2.7 Amino acid digestibility determinations of Prolina soybean meal and commercially available soybean meal samples used in the dietary treatments for Experiment 2.2.

Amino Acids	Prolina Soybean Meal[1]	Commercially Available Soybean Meal[2]
	(% digestibility[3])	
Aspartic Acid	83.2	93.9
Threonine	83.2	88.4
Serine	86.0	87.5
Glutamic Acid	88.2	92.2
Alanine	80.9	82.7
Valine	80.2	86.3
Isoleucine	81.2	88.9
Leucine	83.3	89.4
Tyrosine	80.3	79.2
Phenylalanine	89.9	95.0
Histidine	79.5	86.2
Lysine	83.8	90.0
Arginine	88.1	90.0

[1] Sample of Prolina high protein soybean meal from the pilot batch.

[2] Sample of commercially available soybean meal (Cargill, Raleigh, NC 27603).

[3] Amino acid digestibilities determined using the cecectomized rooster method in the laboratory of Dr.Carl Parsons, Animal Science Department, University of Illinois, Urbana, IL 61801.

Table 2.8. Effect of soybean meal source on body weight (BW), cumulative feed conversion ratio (FCR), and percentage livability of male broiler chickens at 0, 7, 14, 21, and 28 days (d) of age in Experiment 2.2.

	0d	7 d			14 d			21 d			28 d		
Soybean Meal Source [4]	Initial BW[1]	BW	FCR[2]	Livability[3]	BW	FCR[2]	Livability[3]	BW	FCR[2]	Livability[3]	BW	FCR[2]	Livability[3]
	(g)	(g)	(g:g)	(%)	(g)	(g:g)	(%)	(g)	(g:g)	(%)	(g)	(g:g)	(%)
SBM	44.7	133.5	1.07[a]	100.00	349.4	1.23	100.00	762.4	1.41	98.44	1173.2	1.49	98.44
BLEND	44.7	138.4	1.07[a]	98.44	353.4	1.24	96.88	774.7	1.39	96.88	1219.6	1.46	96.88
PROLINA	44.6	131.5	1.03[b]	100.00	349.7	1.22	98.44	766.7	1.39	96.88	1178.4	1.46	96.88
SE	0.4	4.8	0.03	-	2.8	0.01	-	8.3	0.04	-	34.8	0.03	-

[a,b] Means in a column within soybean meal source with no common superscript differ significantly ($P \leq 0.05$)
[1] Initial BW measured at hatch before feeding of the experimental diets began
[2] FCR = cumulative feed consumed to age ÷ live BW. Feed consumption began at 0 d
[3] Percentage birds remaining alive at the respective ages
[4] Represents the dietary treatments created by substituting by weight into a basal diet the following soybean meal sources: a commercially available soybean meal (SBM), a 1:1 blend of the commercially available soybean meal and the Prolina soybean meal from the pilot batch (BLEND), and the Prolina soybean meal from the pilot batch (PROLINA).

dietary treatment through 28 d. The FCR and livability demonstrated by these broilers improved as dietary amino acid levels increased with no detrimental effects of excess dietary amino acids observed.

Overall, modern strains of commercial broilers do appear to utilize a higher level of dietary amino acids than was suggested by the NRC and the impact of this was observed during the entire experiment. Therefore, to maximize the genetic potential of these birds, nutritionists may choose to provide higher levels of amino acids in the diet of male broilers through the use of specific natural feed ingredients or synthetic amino acids.

Experiment 2.2. Experiment 2.2 demonstrated the efficacy of higher protein feed ingredients such as Prolina soybean meal. However, it was difficult to make a true comparison of this specific batch of Prolina soybean meal and a commercially available soybean meal due to the pilot processing method and the second processing that was required for the Prolina. No commercially available soybean meal was reprocessed in this same manner. However, this trial did screen for obvious detrimental effects that Prolina soybean meal, in the diet for a broiler male, could have produced.

Amino acids analyses of the sample of Prolina soybean meal and the commercially available soybean meal in Experiment 2.2 showed that the two samples were similar in amino acid profile. The young male broilers that received diets with each of these responded similarly with regards to growth. At 7 d the PROLINA and BLEND treatments had a significantly better FCR than the SBM treatment. However, this could have been either a result of enhanced nutritional value due to plant breeding or a consequence of the second processing that the PROLINA received. This second processing may have caused several changes. First of all, the Prolina soybean meal had a lower moisture level and therefore a less dilute nutritional content and consequently added a higher level of nutrients to the diets when substituted by weight. Also, the second processing may have caused a complete destruction of any anti-nutritional factors that young broilers might be sensitive to while increasing availability of some critical nutrients. It was interesting to note that the broilers that received the BLEND treatment had a numerically higher BW at 7 d and throughout the trial. This suggested that there was a complimentary pattern created when the nutritional patterns of the Prolina and commercially available soybean meals were blended.

Birds on the SBM and PROLINA dietary treatments performed similarly. This would suggest that batch of Prolina soybean meal proved to be a good substitute for commercially available soybean meals in young broiler diets. With Prolina as the soybean meal source, the birds exhibited excellent BW, FCR and livability. No detrimental effects were observed as a result of the feeding of Prolina soybean meal. Subsequent studies would evaluate more closely the comparison between Prolina and commercially available soybean meals in larger scale broiler feeding trials.

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CHAPTER 3

Establishing the soybean meal produced from Prolina high protein cultivar to be an adequate feedstuff in male broiler diets

ABSTRACT. Two experiments (3.1 and 3.2) were conducted to compare the relative value of Prolina soybean meal and a commercially available soybean meal in broiler diets. Both of these soybean meals were processed at the same commercial plant within a similar timeframe. Prolina meal possessed higher fiber due to the relatively small lot of beans being air-dried while the commercial soybeans used in the comparison were mechanically dried. The difference in soybean moisture caused more hulls to be retained during crushing of the Prolina. Toasted soybean hulls or Solka Floc powdered cellulose were used to dilute the commercially available soybean meal to a similar fiber level as the Prolina soybean meal. In Experiment 3.1 broiler starter and grower diets were formulated to meet NRC (1994) recommended minimums for CP. In Experiment 3.2 broiler starter and grower diets were formulated to meet 100 % and 110 % of the NRC recommended minimums for the amino acids lysine, methionine, and methionine + cystine. For both experiments the treatments were created using direct substitution by weight of the following soybean meals as the soybean meal source: the commercially available soybean meal (SBM), the commercially available soybean meal with soybean hulls (SBM + HULLS), the commercially available soybean meal with Solka Floc (SBM + SF), and the Prolina soybean meal (PROLINA). Experiments 3.1 and 3.2 consisted of four treatments and eight treatments, respectively. Bird BW and feed consumption were measured weekly and FCR was calculated at weekly intervals. For both experiments, no significant differences were observed between soybean meal treatments for BW. For Experiment 3.2, birds receiving the higher CP diet (110%) had

better overall performance. In general, it was found that Prolina soybean meal could be used to substitute for a commercially available soybean meal with no detrimental effects and broilers could respond to dietary amino acids in excess of the NRC recommended minimums.

Introduction

The process of oil extraction from the soybean results in a residual soybean meal that has been used by the livestock industry around the world as a major feedstuff for poultry and swine. This has made the livestock feeding industry one of the largest 'end users' of the soybean. Since current plant breeding programs, like that of the BBI (USB, 2000), will produce a number of soybean cultivars that have enhanced value traits, for instance increased oil and/or protein, there was a need to evaluate the 'by-products.' Therefore the usefulness of new cultivars to produce oil-extracted high protein soybean meal as a valuable by-product that would enter poultry feeds needed to be assessed.

The Prolina soybean cultivar represents an early form of a 'designer' soybean that had specific enhanced traits while still maintaining reasonable agronomic values. Prolina soybeans were grown in an identity-preserved pilot plot for initial testing. By using analyses of the whole bean and projection equations, the CP level of the Prolina soybean meal was predicted to be higher (~55% CP) than that of the typically used commercial soybean meal (~48% CP) (Personal communication with Dr. J. Burton, NC State University, Raleigh, NC 27512). In Chapter 2, a pilot batch of Prolina soybeans was processed and the bean meal was used in Experiment 2.2. Analyses of the pilot batch of Prolina soybean meal indicated that the CP of the sample was slightly higher than that of typical soybean meal and the amino acid profiles and amino acid digestibilities were similar in both soybean meal samples

(Chapter 2, Tables 2.3, 2.4, and 2.5). The results of Experiment 2.2 demonstrated that the young male broilers obtained no BW disadvantage when fed diets formulated with the Prolina soybean meal. Although the expected benefits of the higher CP in Prolina soybean meal were not apparent, it was equally important that there were no detrimental effects on bird performance observed. The broilers on the Prolina soybean meal treatments performed equally as well as those being fed the commercially available soybean meal treatments. Therefore, it was concluded that the evaluations of Prolina would continue with a second and much larger identity-preserved planting for the purpose of producing commercially oil-extracted soybean meal for larger scale poultry feeding trials.

The preliminary feeding trials conducted with young male broilers in Experiments 2.1 and 2.2 outlined some of the important factors to consider when evaluating a soybean meal from a cultivar as a feedstuff. In Experiment 2.1, the early sensitivity of young male broilers to increased dietary CP, based on the amino acids lysine, methionine, and methionine + cystine, was established. It was shown that young male broilers could utililize these amino acids at levels that were in excess of the NRC recommendations, as was evidenced by improved BW and FCR. Therefore, it seemed reasonable that a direct substitution method of evaluation for a soybean meal made from a high protein cultivar, such as Prolina, in place of a typical commercially available soybean meal could be carried out in broiler diets that were formulated to the NRC recommendations for minimum dietary amino acid levels. Under such conditions the additional amino acids predicted to be present in the Prolina soybean meal would be expected to produce birds with improved BW and FCR as compared to those fed the commercially available soybean meal.

In Experiment 2.2 only the Prolina was processed at the pilot plant. Therefore, it was somewhat difficult to make comparisons between Prolina soybean meal and the commercially available meal that had been processed on a commercial scale. To avoid this, it would be important that the soybeans to be compared would need to be grown in similar locations, the processing method would have to be the same for both, and the non-protein components of the two soybean meals would need to be as equal as possible to ascertain the true effects of the available protein and amino acids in the test cultivar. For example, certain components of the soybean meal, such as tannins and protease inhibitor levels, could negatively affect the digestion and absorption of proteins and amino acids in young broilers and could be present at higher than normal levels when beans have not been processed properly (Garlich, 1988). Other elements such as fiber, when present at high levels, may impact gut viscosity and can inhibit digestion and absorption of nutrients and decrease the ability of the birds to utilize dietary CP (Klasing, 1998).

In continuing the evaluation of the Prolina soybean meal as a substitute for typical commercially available soybean meal, it was also important to discover the effects on broiler live performance and carcass composition to typical market ages. As a greater quantity of the Prolina soybean meal would be available for use in experimental diets, it would be possible to move the experiments from battery cages to floor pens within typical curtain-sided broiler houses to more closely mimic commercial growing conditions.

Although the recommended requirement for amino acids as a percentage of the diet decreases as the bird ages (NRC, 1994) due to increased feed consumption, there have been reports to suggest that male broiler chickens can utilize levels of specific amino acids beyond 21 d higher than those recommended by the NRC (Klasing, 1998; Prak et al., 1999).

Theoretically, the predicted higher protein content of the Prolina soybean meal would benefit birds at all life stages.

Materials and Methods

Prolina Soybean Meal Production-Main Batch. Following the production and evaluation of the pilot batch of Prolina soybean meal, a second and larger plot of Prolina soybeans was grown the next season in Northeastern North Carolina (Eure Farms for NC Foundation Seed Producers, Raleigh, NC 27654) using standard identity preservation procedures. After harvest, the Prolina soybeans were air-dried in bulk bags and taken by truck from the growing farm to the Perdue Farms, Inc. Soybean Processing Plant (Cofield, NC 27922) with precautions taken to avoid any contamination by other soybeans (standard identity preservation procedures). Approximately 1000 bushels of Prolina soybeans were dumped from the truck into a specifically fabricated opening in the elevator leg that led to the holding bin above the soybean crusher just as the holding bin was running empty. The flow rate of soybeans through the processing procedure had been previously determined in order to calculate the position of the Prolina soybeans in the system and ensure identity preservation. Throughout the process, the location of the Prolina was monitored using NIR spectroscopy and flow rate calculations. Processing methods were according to standard soybean processing procedures used in industry. Soybeans were cleaned, cracked, and de-hulled as thoroughly as possible. However, Prolina soybean hulls were not removed as completely as would normally be the case due to the higher moisture content (13%) of this batch of air-dried Prolina soybeans versus the moisture (10%) of typical mechanically dried soybeans. The resulting soy chips were conditioned and rolled into full fat flakes. The oil was removed using the full hexane method of extraction. Approximately one ton of Prolina beans were allowed to pass through the system before Prolina soybean meal collection began to ensure clearing of residual local beans. After passing through the processing line, 12 tons of bean meal was directed out to a clean, empty storage bin over the truck load-out. The de-hulled, de-fatted Prolina soybean meal and an equal amount of soybean meal made the previous day from locally grown commercial soybeans were then taken in separate trucks and stored in separate bins at the North Carolina State University (NCSU) poultry feed mill facility.

Since the Prolina soybean meal had higher fiber content due to the excess amount of hulls remaining in the meal, the appropriate adjustment was made by adding a fiber source to the commercial variety soybean meal in order to bring both meals to the same percentage fiber. The fiber correction formula was calculated by taking the difference in analyzed fiber values of the two soybean meals and dividing by the amount of fiber in soy hulls to determine the percentage of fiber source to be added to the commercial soybean meal[1]. Soybean hulls used for dilution were toasted using an autoclave method to insure destruction of anti-nutritional factors (Loon, 2002) and were tested using the Soy Chek rapid urease test (LSB Products, Manhattan, KS 66502). This resulted in similar fiber content for the two soybean meals. Samples of these soybean meals and soybean hulls were sent to independent laboratories for proximate analyses, amino acid analyses, amino acid digestibilities, and true ME determination. This second and main batch of Prolina soybean meal was used throughout the remaining experiments reported in Chapters 3, 4, and 5.

[1] ((Analyzed percentage fiber in PROLINA-Analyzed percentage fiber in SBM) / Percentage fiber in soybean hulls)*100

Experiment 3.1

Birds and Facility. Arbor Acres Yield male x Arbor Acres FSY female strain broilers were sexed and individually identified with neck tags at hatching. A total of 800 male broilers were randomly distributed among 32 pens with 25 birds per pen. Each pen in the curtain-sided house measured 3.7 m in length and 1.2 m in width. Broiler chicks were placed on previously used wood shavings that had been covered with a thin layer of fresh pine shavings. Five 75,000 BTU space heaters were hung from the ceiling over the central walkway of the house. The heater exhausts were directed towards four, ¼ horsepower fans (1600 rpm and 60 cm diameter blade) that were directed upwards to a flat metal ceiling to ensure proper temperature distribution and de-stratification. Litter temperature was 32 C at placement and was decreased by 3 C weekly until 24 C was reached. Birds received 23 h of light supplied by three rows of 25-watt incandescent bulbs throughout the experiment. There was one row on each side of the house with one bulb located over the center of each pen and one row located over the center of the central walkway. Natural light entered the pens during daylight hours through operable translucent curtains.

Birds were provided feed and water for *ad libitum* consumption using two tube feeders and one bell waterer per pen. Supplemental feeders and waterers were placed on the floor of each pen and provided from hatch to 7 d of age. Initially, 454 grams of crumbled starter feed was placed per bird in each pen. An additional 682 grams of pelleted starter feed per bird was added at 7 d. At 21 d, pelleted grower feed was added on top of the remaining starter feed. Birds consumed grower feed to the end of the experiment. At 42 d, access to feed was discontinued by raising the feeders 12 h prior to processing with the birds maintaining access to water.

Diets. Corn-soy basal starter and grower diets were formulated using a commercially available soybean meal to a calculated basal ME of 3.2 kcal ME/g and with 100% of the NRC (1994) recommended minimum values for lysine, methionine, and methionine + cystine. Four dietary treatments were created by substituting Prolina soybean meal (PROLINA), commercially available soybean meal processed in the same facility as Prolina (SBM), the commercially available soybean meal with soybean hulls (SBM + HULLS), or the commercially available soybean meal with Solka Floc[2] (SBM + SF) as the soybean meal source in each diet. Samples of each diet were subjected to proximate analyses as described in Chapter 2, Experiment 2.2.

Data Collection. Feed consumption and BW were measured weekly on a pen basis from placement to 42 d. House temperature was monitored twice daily by observing eight recording thermometers located at bird level throughout the house. Dead birds were weighed and recorded twice daily. The FCR[3] and AdjFCR[4] were calculated at weekly intervals. At 42 d, three birds from each pen were selected to be processed for carcass yield by generation of random neck tag numbers. As described by Brake et al. (1993), each bird was weighed live, electrically stunned, killed by exsanguination, and allowed to bleed for 180 s. The carcass was placed in a hot water scalder (63 C) for approximately 120s and then placed in a rotary drum picker (Ashley Sure-Pick Model 30, Ashley Machine, Inc., Greensburg, IN 47240) for 30s for feather removal. No correction was made for scald water uptake. The head, neck, shanks, and feet were removed and the bird was eviscerated by cutting around the vent and removing the viscera without disturbing the abdominal fat pad. This was

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[2] Solka Floc (SF), a powdered cellulose produced by Fibre Sales and Development Corporation, Checkerboard Square, St. Louis, MO 63164

[3] FCR = Total feed consumed ÷ Total BW of surviving birds

[4] AdjFCR = Total feed consumed ÷ (BW of surviving birds + total terminal BW of birds that died)

performed by two experienced staff members. The lungs were left in the eviscerated carcass and the neck was placed inside the carcass. Upon further processing, the neck was taken out of the carcass and carcass weight was measured. The abdominal fat pad was removed and the carcass was placed on a processing cone for cut-up and de-boning. Neck, abdominal fat pad, wings, legs, thighs, breast skin, *Pectoralis major* and *Pectoralis minor* were dissected away and placed on the scale consecutively. The remaining back and rib cage were weighed intact. The weight of each carcass component was determined by difference. All weights were recorded to the nearest gram. Four experienced people conducted the cut-up and de-boning procedures. All data were expressed as a raw weight in grams and as a percentage of live BW.

Statistical Analysis. The experimental design consisted of four soybean meal sources as dietary treatments within a randomized complete block design with 32 experimental units. There were 16 pens on each side of the central walkway with a central feed room dividing the house into four blocks consisting of eight pens each. There were eight replicate pens per interaction mean. Statistical analysis was carried out using a one-way analysis of variance with the General Linear Models procedure of SAS® institute (SAS Institute, Inc., Cary, NC 1999-2001). Error was calculated from between replicate pen variation (residual). Means were partitioned using the Duncan option. Statements of statistical significance were based on $P \leq 0.05$.

Results

Soybean Meal. The percentage moisture, fat, CP, crude fiber, and ash, as determined by proximate analyses for the Prolina soybean meal, the commercially available soybean meal, and toasted soybean hulls are shown in Table 3.1. No significant differences were found between the soybean meal samples. Soybean hulls possessed percentage moisture, fat, CP, crude fiber and ash values that were within the expected range.

Amino Acid Analyses. The percentage total amino acids for Prolina soybean meal, commercially available soybean meal and toasted soybean hulls are shown in Table 3.2. The amino acid profiles of the two soybean samples appeared to be similar. However, the results of this analysis indicated that the threonine and serine levels appeared to be lower in the Prolina soybean meal as compared to that of the commercial meal. This analysis indicated that the Prolina has a higher level of leucine and slightly lower amount of isoleucine. The amino acid profile for the soybean hulls was within the expected range.

Amino Acid Digestibility and Metabolizable Energy Analyses. The percentage amino acid digestibilities for Prolina soybean meal, commercially available soybean meal, and commercially available soybean meal with hulls are shown in Table 3.3. The results of these analyses suggested that the Prolina soybean sample had a slightly higher percentage digestibility for all amino acids tested as compared to the other soybean meal samples.

Gross and total ME for Prolina soybean meal, commercially available soybean meal, and commercially available soybean meal with hulls are shown in Table 3.3. Gross energy was similar for all three soybean meal samples. True metabolizable energy adjusted for nitrogen (TMEn) was highest in the commercial variety of soybean meal as compared to the Prolina soybean meal with the commercially available soybean meal with hulls having an intermediate ME value.

Diet Analyses. The percentage dietary CP and ME values that were calculated using the linear programming feed formulation method and the results of the analyses for the

Table 3.1. Proximate analyses of Prolina soybean meal, a commercially available soybean meal and soybean hulls that were used in Experiments 3.1, 3.2, 4, and 5.

Proximate Analyses[1]	Prolina Soybean Meal[2]	Commercially Available Soybean Meal[3]	Soybean Hulls[4]
	(%)		
Moisture, %	12.10	12.18	9.22
Fat, %	1.10	1.04	1.78
Crude protein, %	48.50	48.18	12.57
Crude fiber, %	4.31	3.74	33.29
Ash, %	6.45	6.20	4.01

[1] Mean of five (5) samples of each soybean meal submitted to Woodson-Tenent Laboratories, Goldston, NC 27252 (4 samples) and Dr. T.P. Mawhinney, Experiment Station Chemical Laboratories, University of Missouri, Colombia, MO 65211 (1 sample). No statistical differences were found between the Prolina soybean meal and the commercially available soybean meal samples.

[2] Samples of soybean meal produced from the main batch of experimental high Protein soybean cultivar Prolina.

[3] Samples of commercially available soybean meal typically used in the broiler industry (Perdue Farms, Cofield, NC 27922).

[4] Sample of soybean hulls typically used in the livestock industry (Cargill, Raleigh, NC 27603).

Table 3.2 Amino acid analyses of Prolina soybean meal, a commercially available soybean meal and soybean hulls that were used in Experiments 3.1, 3.2, 4, and 5.

Amino Acids[1]	Prolina Soybean Meal[2]	Commercially Available Soybean Meal[3]	Soybean Hulls[4]
		(%)	
Taurine	0.03	0.08	0.08
Hydroxyproline	0.00	0.07	0.55
Aspartic Acid	5.53	5.54	0.79
Threonine	1.85	1.94	0.35
Serine	1.84	2.40	1.98
Glutamic Acid	9.45	9.10	0.91
Proline	2.43	2.40	0.45
Lanthionine	0.03	0.00	0.00
Glycine	1.98	2.05	0.83
Alanine	2.14	2.12	0.38
Cystine	0.86	0.85	0.18
Valine	2.33	2.38	0.44
Methionine	0.70	0.72	0.11
Isoleucine	2.09	2.20	0.30
Leucine	3.93	3.79	0.53
Tyrosine	1.73	1.75	0.43
Phenylalanine	2.47	2.51	0.32
Hydroxylysine	0.01	0.01	0.00
Histidine	1.29	1.37	0.26
Ornithine	0.05	0.05	0.00
Lysine	3.23	3.18	0.67
Arginine	3.65	3.68	0.42
Tryptophan	0.77	0.76	0.07
Methionine + Cystine	1.56	1.57	0.29

[1]Amino acid analyses performed on one sample of soybean meal each by the laboratory of Dr. T.P. Mawhinney, Experiment Station Chemical Laboratories, University of Missouri, Colombia, MO 65211.

[2] Sample of soybean meal from the main batch of experimental high Protein soybean cultivar Prolina.

[3] Sample of commercially available soybean meal typically used in the broiler industry (Perdue Farms, Cofield, NC 27922).

[4] Sample of soybean hulls typically used in the livestock industry (Cargill, Raleigh, NC 27603).

Table 3.3. Amino acid digestibility determinations from samples of Prolina soybean meal, a commercially available soybean meal and soybean hulls that were used in Experiments 3.1, 3.2, 4, and 5.

Amino Acids	Prolina Soybean Meal[1]	Commercially Available Soybean Meal[2]	Commercially Available Soybean Meal with Hulls[3]
		(% digestibility[4])	
Aspartic Acid	91.3	88.9	89.2
Threonine	92.2	88.4	89.1
Serine	91.3	87.5	89.4
Glutamic Acid	94.7	92.2	92.2
Alanine	86.4	82.7	83.9
Cystine	89.8	87.1	90.6
Valine	89.4	86.3	87.4
Methionine	79.6	78.5	78.8
Isoleucine	91.2	88.9	88.8
Leucine	91.7	89.4	89.6
Tyrosine	85.0	79.2	81.8
Phenylalanine	95.6	95.0	92.7
Histidine	90.9	86.2	91.0
Lysine	91.3	90.0	91.3
Arginine	93.0	90.0	91.6
Energy[5]			
Dry matter, %	91.2	90.20	91.3
Gross Energy, kcal/g	4.31	4.25	4.29
TME_n, kcal/g dry matter	2.75	2.98	2.81

[1] Sample of soybean meal from the main batch of experimental high protein soybean cultivar Prolina (PROLINA).
[2] Sample of commercially available soybean meal (SBM) typically used in industry (Perdue Farms, Cofield, NC 27922).
[3] Sample of commercially available soybean meal with soybean hulls (SBM + HULLS) added for fiber correction.
[4] Amino acid digestibilities determined using the cecectomized rooster method by the laboratory of Dr. Carl Parsons, University of Illinois, Urbana, IL 61801.
[5] Energy values by the Anderson et al.(1958) method of TMEn determination.

percentage moisture, CP, crude fat, crude fiber, and ash for the starter and grower experimental diets are shown in Table 3.4 and 3.5, respectively. For the starter diet (Table 3.4), the analyzed CP values of the samples were slightly higher than the calculated value. For the grower diet (Table 3.5) the analyzed CP values were in good agreement with the calculated values.

The percentage CP, moisture, fat and ash for the PROLINA, SBM, SBM+SF, and SBM+HULLS samples of the starter and grower dietary treatments were similar and within normally expected variation. The percentage crude fiber was slightly higher in PROLINA as compared to the other treatments in both the starter and grower diets.

Body Weight. Table 3.6 shows the BW of the birds fed the PROLINA, SBM, SBM+SF and SBM+HULLS dietary treatments at placement, 7, 14, 21, 28, 35, and 42 d. No significant differences in BW were found as a result of soybean meal source throughout the experiment.

Adjusted Feed Conversion Ratio. Cumulative AdjFCR is shown in Table 3.7. No differences as a result of the soybean meal source were seen from hatch to 7, 14, 21 and 28 d. However, by 35 d, the birds on the SBM dietary treatments exhibited significantly better AdjFCR as compared to the SBM+HULLS, SBM+SF and PROLINA treatments but this effect was no longer seen at 42 d.

Livability. The percentage birds alive at 7, 14, 21, 28, 35, and 42 d for the different soybean meal sources are shown in Table 3.8. No statistically significant differences in livability were observed in the trial.

Carcass Composition. The effect of soybean meal source on carcass composition is shown in Table 3.9. There were no significant differences for neck, legs, thighs, wings,

Table 3.4. Compositions and analyses of starter diets[1] in Experiment 3.1.

Variable Ingredients	Constants	SBM[2]	SBM + SF[3]	SBM + HULLS[4]	PROLINA[5]
			(%)		
Commercial soybean meal[2]		34.32	33.29	33.29	…
Solka Floc[3]		…	1.03	…	…
Soybean hulls[4]		…	…	1.03	…
Prolina soybean meal[5]		…		…	34.32
Corn	56.0				
Poultry fat	5.48				
Dicalcium phosphate	1.85				
Limestone (calcium carbonate)	1.06				
Salt (NaCl)	0.53				
Trace mineral premix[6]	0.20				
Vitamin premix[7]	0.05				
Choline chloride (60%)	0.20				
Liquid methionine analogue	0.14				
Coccidiostat	0.07				
Selenium premix[8]	0.10				
Total		100.00	100.00	100.00	100.00
Calculated Analyses[9]					
Metabolizable energy, kcal/kg	3200				
Crude protein, %	21.85				
Actual Analyses[10]					
Crude protein, %		22.5	22.3	22.2	22.2
Moisture, %		14.0	13.5	12.8	13.5
Fat, %		4.8	4.8	5.8	5.0
Fiber, %		2.2	2.0	2.0	1.9
Ash, %		5.2	5.2	5.2	5.5

[1] Formulated at 100% of the NRC (1994) recommendations for the amino acids methionine, cystine, methionine + cystine and lysine (100-NRC).

[2] A commercially available soybean meal typically used in industry was added to the constant ingredients (SBM).

[3] Solka Floc , a powdered cellulose (Fibre Sales and Development Corporation, Checkerboard Square, St. Louis, MO 63164), added to commercially available soybean meal by weight as a fiber source (SBM+SF).

[4] Soybean hulls as typically used in industry, added to commercially available soybean meal by weight as a fiber source (SBM +HULLS).

[5] The experimental soybean meal from the main batch of Prolina soybean meal was added to constant ingredients by weight (PROLINA).

[6] Supplied per kg diet: manganese 120 mg, zinc 120 mg, iron 80 mg, copper 10 mg, iodine 2.5 mg, and cobalt 1.0 mg.

[7] Supplied per kg diet: retinol 6600 IU, cholecalciferol 2000 IU, vitamin E 33 IU, vitamin B_{12} 19.8 ug, riboflavin 6.6 mg, niacin 55 mg, pantothenic acid 11 mg, vitamin K 2 mg, folic acid 1.1 mg,thiamine 2 mg, pyridoxine 4 mg, and biotin 126 ug.

[8] Selenium premix provided 0.10 mg selenium/kg of diet.

[9] Diets calculated using the linear programming method of feed formulation.

[10] Proximate analyses performed by Woodson-Tenent Laboratories, Goldston, NC 27252.

Table 3.5. Compositions and analyses of grower diets[1] used in Experiment 3.1.

Variable Ingredients	Constants	SBM[2]	SBM + SF[3]	SBM + HULLS[4]	PROLINA[5]
			(%)		
Commercial soybean meal[2]		28.09	27.25	27.25	…
Solka Floc[3]		…	0.84	…	…
Soybean hulls[4]		…	…	0.84	…
Prolina soybean meal[5]		…	…	…	28.09
Corn	63.3				
Poultry fat	4.46				
Dicalcium phosphate	1.91				
Limestone (calcium carbonate)	1.07				
Salt (NaCl)	0.52				
Trace mineral premix[6]	0.20				
Vitamin premix[7]	0.05				
Choline chloride (60%)	0.20				
Liquid methionine analogue	0.03				
Coccidiostat	0.07				
Selenium premix[8]	0.10				
Total		100.00	100.00	100.00	100.00
Calculated Analyses[9]					
Metabolizable Energy, kcal/kg	3200				
Crude protein, %	19.46				
Actual Analyses[10]					
Crude Protein, %		19.6	20.1	19.6	20.4
Moisture, %		12.4	12.1	12.6	11.9
Fat, %		5.6	5.5	5.4	5.6
Fiber, %		2.4	2.0	2.1	2.1
Ash, %		5.4	5.3	5.2	5.4

[1] Formulated at 100% of the NRC (1994) recommendations for the amino acids methionine, cystine, methionine + cystine and lysine (100-NRC).

[2] A commercially available soybean meal typically used in industry was added to the constant ingredients (SBM).

[3] Solka Floc , a powdered cellulose (Fibre Sales and Development Corporation, Checkerboard Square, St. Louis, MO 63164), added to commercially available soybean meal by weight as a fiber source (SBM+SF).

[4] Soybean hulls as typically used in industry, added to commercially available soybean meal by weight as a fiber source (SBM +HULLS).

[5] The experimental soybean meal from the main batch of Prolina soybean meal was added to constant ingredients by weight (PROLINA).

[6] Supplied per kg diet: manganese 120 mg, zinc 120 mg, iron 80 mg, copper 10 mg, iodine 2.5 mg, and cobalt 1.0 mg.

[7] Supplied per kg diet: retinol 6600 IU, cholecalciferol 2000 IU, vitamin E 33 IU, vitamin B_{12} 19.8 ug, riboflavin 6.6 mg, niacin 55 mg, pantothenic acid 11 mg, vitamin K 2 mg, folic acid 1.1 mg,thiamine 2 mg, pyridoxine 4 mg, and biotin 126 ug.

[8] Selenium premix provided 0.10 mg selenium/kg of diet.

[9] Diets calculated using the linear programming method of feed formulation.

[10] Proximate analyses performed by Woodson-Tenent Laboratories, Goldston, NC 27252.

Table 3.6. Effect of soybean meal source on body weight (BW) of male broiler chickens at 7, 14, 21, 28, 35 and 42 days (d) of age in Experiment 3.1.

	BW						
Soybean Meal Source[1]	Initial[2]	7 d	14 d	21 d	28 d	35 d	42 d
	(g)						
SBM	38.7	147.8	417.0	877.9	1472.7	2210.5	2726.4
SBM+HULLS	38.7	143.8	411.2	868.9	1450.3	2158.4	2669.1
SBM+SF	38.9	146.4	408.9	862.5	1448.7	2164.4	2682.0
PROLINA	38.7	154.5	421.3	881.0	1469.3	2178.9	2771.4
SE	0.1	4.0	4.9	7.3	10.8	20.2	23.9

[a,b] Means in a column within soybean meal source with no common superscript differ significantly ($P \leq 0.05$). No statistically significant differences were found.

[1] Represents either a commercially available soybean meal as used in industry (SBM), commercially available soybean meal with added soybean hulls (SBM + HULLS) or Solka Floc (SBM + SF), and the experimental soybean meal from the main batch (PROLINA).

[2] Initial BW measured at placement at which point feeding of the experimental diets began.

Table 3.7. Effect of soybean meal source on mortality adjusted feed conversion ratio (AdjFCR) of male broiler chickens to 7, 14, 21, 28, 35 and 42 days (d) of age in Experiment 3.1.

Soybean Meal Source [1]	AdjFCR[2]					
	0-7 d	0-14 d	0-21 d	0-28 d	0-35 d	0-42 d
	(g:g)					
SBM	1.11	1.26	1.38	1.49	1.58[b]	1.82
SBM+ HULLS	1.09	1.27	1.39	1.52	1.62[a]	1.85
SBM+SF	1.05	1.27	1.39	1.51	1.61[a]	1.85
PROLINA	1.06	1.26	1.37	1.51	1.61[a]	1.82
SE	0.03	0.003	0.01	0.01	0.01	0.02

[a,b] Means in a column within soybean meal source with no common superscripts differ significantly ($P \leq 0.05$).

[1] Represents either a commercially available soybean meal as used in industry (SBM), the commercially available soybean meal with added soybean hulls (SBM + HULLS) or Solka Floc (SBM + SF) , and the experimental soybean meal from the main batch (PROLINA).

[2] AdjFCR= feed consumed to age / (live BW + weight of dead birds).

Table 3.8. Effect of soybean meal source on livability of male broiler chickens to 7, 14, 21, 28, 35 and 42 days (d) of age in Experiment 3.1.

Soybean Meal Source [1]	Livability [2]					
	0-7 d	0-14 d	0-21 d	0-28 d	0-35 d	0-42 d
	(%)					
SBM	100.0	100.0	98.5	97.5	96.0	94.5
SBM+ HULLS	99.5	98.0	97.0	95.0	93.4	90.5
SBM+SF	100.0	99.0	97.5	97.5	95.5	93.5
PROLINA	99.0	98.0	98.0	97.0	95.5	92.5
SE	0.4	0.5	0.6	0.7	0.8	1.0

[a,b] Means in a column within soybean meal source with no common superscripts differ significantly ($P \leq 0.05$).

[1] Represents either a commercially available soybean meal as used in industry (SBM), the commercially available soybean meal with added soybean hulls (SBM + HULLS) or Solka Floc (SBM + SF), and the experimental soybean meal from the main batch (PROLINA).

[2] Percentage birds remaining alive at the respective ages.

Table 3.9. Effect of soybean meal source on carcass yield of male broiler chickens at 42 days (d) of age in Experiment 3.1.

Soybean Meal Source [1]	Live BW	Dressed Carcass	Neck	Fat Pad	Legs	Thighs	Wings	Breast Skin	*Pectoralis major*	*Pectoralis minor*	Ribs and Back
	(g)	(g/100g carcass)									
SBM	2654.8	69.9	4.61	1.39[a]	9.85	12.34	7.63	1.90	15.62	3.81	17.04
SBM+ HULLS	2611.2	68.9	4.61	1.19[ab]	10.11	12.29	7.66	1.99	15.28	3.67	16.49
SBM+SF	2656.4	69.7	4.54	1.04[b]	10.17	12.52	7.83	1.73	15.37	3.67	16.95
PROLINA	2663.3	69.6	4.47	1.08[b]	9.94	12.51	7.73	1.94	15.64	3.70	16.77
SE	20.6	0.2	0.03	0.08	0.07	0.06	0.08	0.06	0.09	0.03	0.12

[a,b] Means in a column within soybean meal source with no common superscript differ significantly ($P \leq 0.05$).

[1] Represents either a commercially available soybean meal as used in industry (SBM), the commercially available soybean meal with added soybean hulls (SBM + HULLS) or Solka Floc (SBM + SF) , and the experimental soybean meal from the main batch (PROLINA).

breast skin, *Pectoralis major, Pectoralis minor,* and ribs combined with back as a percentage of live BW for the soybean meal sources. However, the birds receiving the SBM treatment had a higher fat pad as a percentage of live BW as compared to the SBM+SF and PROLINA treatments with the SBM+HULLS treatment intermediate.

Experiment 3.2

Materials and Methods

Birds and Facility. Ross 344 X 508 strain broilers were sexed and individually identified with neck tags at hatch. A total of 704 male broilers were randomly distributed among 32 pens with 22 birds per pen. The air flow systems, heating components, and lighting schedule were set up as described in Experiment 3.1. Birds were provided feed and water for *ad libitum* consumption using two tube feeders and one bell waterer per pen. Supplemental feeders and waterers were placed on the floor of each pen and were provided from hatch to 7 d. Initially, 1135 grams of crumbled starter feed was placed per bird in each pen. At 21 d, the pelleted grower feed was added on top of the remaining starter feed. Birds consumed grower feed to the end of the experiment. At 42 d, access to feed was discontinued by raising feeders 12 hours prior to processing with the birds maintaining access to water.

Diets. Starter and grower corn-soy basal diets were formulated using a commercially available soybean meal as the soybean meal source to a calculated basal ME of 3.2 kcal ME/g and at either 100% (100-NRC) or 110% (110-NRC) of the NRC (1994) recommended values for lysine, methionine, and methionine + cystine. Eight dietary treatments were created by substituting by weight PROLINA, SBM, SBM + HULLS, or SBM with Solka Floc (SBM + SF) into the 100-NRC and 110-NRC basal diets (Tables 3.10 and 3.11).

Table 3.10. Compositions of starter diets in Experiment 3.2.

Ingredients	100-NRC Series[1] Constants	SBM[3]	SBM + SF[4]	SBM + HULLS[5]	PROLINA[6]	110-NRC Series[2] Constants	SBM[3]	SBM + SF[4]	SBM + HULLS[5]	PROLINA[6]
			(%)					(%)		
SBM[3]		34.32	33.29	33.29	…		39.82	38.63	38.63	…
Solka Floc[4]		…	1.03	…	…		…	1.19	…	…
Soybean hulls[5]		…	…	1.03	…		…	…	1.19	…
PROLINA[6]		…	…	…	34.32		…	…	…	39.82
Corn	56.00					49.60				
Poultry fat	5.48					6.39				
Dicalcium phosphate	1.85					1.80				
Limestone	1.06					1.06				
Salt (NaCl)	0.53					0.53				
Trace mineral premix[7]	0.20					0.20				
Vitamin premix[8]	0.05					0.05				
Choline chloride (60%)	0.20					0.20				
Liquid met analogue	0.14					0.18				
Coccidiostat	0.07					0.07				
Selenium premix[9]	0.10					0.10				
Total		100.0	100.0	100.0	100.0		100.0	100.0	100.0	100.0
Calculated analyses										
Metabolizable energy, kcal/kg	3200					3200				
Crude protein, %	21.85					23.85				

[1] Formulated at 100% of the NRC (1994) recommendations for the amino acids lysine, methionine, and methionine + cystine (100-NRC).

[2] Formulated at 110% of the NRC (1994) recommendations for the amino acids lysine, methionine, and methionine + cystine (110-NRC).

[3] A commercially available soybean meal typically used in industry (SBM) was added to the constant ingredients to create dietary treatment SBM.

[4] Solka Floc (SF), a powdered cellulose (Fibre Sales and development Corporation, Checkerboard Square, St. Louis, MO 63164), added to SBM as a fiber source by weight to create (SBM+SF).

[5] Soybean hulls as typically used in industry, added to SBM as a fiber source by weight add to create (SBM +HULLS).

[6] The experimental soybean meal from the main batch (PROLINA) added to constant ingredients by weight to create the dietary treatment PROLINA.

[7] Supplied per kg diet: manganese 120 mg, zinc 120 mg, iron 80 mg, copper 10 mg, iodine 2.5 mg, and cobalt 1.0 mg.

[8] Supplied per kg diet: retinol 6600 IU, cholecalciferol 2000 IU, vitamin E 33 IU, vitamin B_{12} 19.8 ug, riboflavin 6.6 mg, niacin 55 mg, pantothenic acid 11 mg, vitamin K 2 mg, folic acid 1.1 mg, thiamine 2 mg, pyridoxine 4 mg, and biotin 126 ug.

[9] Selenium premix provided 0.10 mg selenium/kg of diet.

Table 3.11. Compositions of grower diets in Experiment 3.2.

	100-NRC Series[1]					110-NRC Series[2]				
Ingredients	Constants	SBM[3]	SBM + SF[4]	SBM + HULLS[5]	PROLINA[6]	Constants	SBM[3]	SBM + SF[4]	SBM + HULLS[5]	PROLINA[6]
			(%)					(%)		
SBM[3]		28.09	27.25	27.25	…		32.82	31.84	31.84	…
Solka Floc[4]		…	0.84	…	…		…	0.98	…	…
Soybean hulls[5]		…	…	0.84			…	…	0.98	…
PROLINA[6]		…	…	…	28.09		…	…	…	32.82
Corn	63.3					57.8				
Poultry fat	4.46					5.23				
Dicalcium phosphate	1.91					1.87				
Limestone	1.07					1.07				
Salt (NaCl)	0.52					0.52				
Trace mineral premix[7]	0.20					0.20				
Vitamin premix[8]	0.05					0.05				
Choline chloride (60%)	0.20					0.20				
Liquid met analogue	0.03					0.07				
Coccidiostat	0.07					0.07				
Selenium premix[9]	0.10					0.10				
Total		100.0	100.0	100.0	100.0		100.0	100.0	100.0	100.0
Calculated analyses										
Metabolizable energy, kcal/kg	3200					3200				
Crude protein, %	19.46					21.22				

[1] Formulated at 100% of the NRC (1994) recommendations for the amino acids lysine, methionine, and methionine + cystine (100-NRC).
[2] Formulated at 110% of the NRC (1994) recommendations for the amino acids lysine, methionine, and methionine + cystine 110-NRC).
[3] A commercially available soybean meal typically used in industry (SBM) was added to the constant ingredients to create dietary treatment SBM.
[4] Solka Floc (SF), a powdered cellulose (Fibre Sales and development Corporation, Checkerboard Square, St. Louis, MO 63164), added to SBM as a fiber source by weight to create (SBM+SF).
[5] Soybean hulls as typically used in industry, added to SBM as a fiber source by weight add to create (SBM +HULLS).
[6] The experimental soybean meal from the main batch (PROLINA) added to constant ingredients by weight to create the dietary treatment PROLINA.
[7] Supplied per kg diet: manganese 120 mg, zinc 120 mg, iron 80 mg, copper 10 mg, iodine 2.5 mg, and cobalt 1.0 mg.
[8] Supplied per kg diet: retinol 6600 IU, cholecalciferol 2000 IU, vitamin E 33 IU, vitamin B_{12} 19.8 ug, riboflavin 6.6 mg, niacin 55 mg, pantothenic acid 11 mg, vitamin K 2 mg, folic acid 1.1 mg, thiamine 2 mg, pyridoxine 4 mg, and biotin 126 ug.
[9] Selenium premix provided 0.10 mg selenium/kg of diet.

Data Collection. Feed consumption and BW were measured weekly on a pen basis from placement to 42 d. House temperature was monitored twice daily by observing eight thermometers hung at bird level throughout the house. Dead birds were weighed and three birds from each pen were selected to be processed for carcass composition as described in Experiment 3.1.

Statistical Analysis. The experimental design was a 2 x 4 factorial with two levels of dietary CP and four soybean meal sources. There were eight dietary treatments within a randomized complete block design with 32 experimental units. There were 16 pens on each side of the central walkway with a center feed room dividing the house into four blocks consisting of eight pens each. There were four replicate pens per diet. Statistical analysis was carried out using a two-way analysis of variance with the General Linear Models procedure of SAS® Institute (SAS Institute,1999-2001). Error was calculated from between replicate pen variation (residual). Means were partitioned using the Duncan option. Statements of statistical significance were based upon $P \leq 0.05$.

Results

Body Weight. The effects of soybean meal source and level of CP in the diet on BW for 7, 14, 21, 28, 35 and 42 d are shown in Table 3.12. There were no significant differences in BW observed between the PROLINA, SBM, SBM+HULLS, or SBM+SF dietary treatments. The birds fed the 110-NRC diet had significantly higher BW at 7, 21, and 28 d as compared to the 100-NRC diets and this effect remained numerically present at 35 d but no differences were observed at 42 d. No interaction between soybean meal source and dietary amino acid levels were observed.

Table 3.12. Effect of soybean meal source and percentage of NRC (1994) amino acid recommendations for lysine, methionine, and methionine + cystine on body weight (BW) of male broiler chickens at 7, 14, 21, 28, 35 and 42 days (d) of age in Experiment 3.2.

Dietary Amino Acids [2]	Soybean Meal Source [3]	BW						
		Initial[1]	7 d	14 d	21 d	28 d	35 d	42 d
		(g)						
100-NRC		47.5	157.1[b]	405.5	810.8[b]	1331.4[b]	1997.4	2658.6
110-NRC		47.0	162.6[a]	411.1	834.3[a]	1369.4[a]	2039.3	2687.6
SE		0.3	2.0	4.1	7.73	11.2	15.6	18.2
	SBM	46.9	157.5	405.3	827.3	1370.2	2047.2	2700.8
	SBM + HULLS	47.3	161.0	415.1	824.3	1351.3	2016.6	2701.4
	SBM + SF	47.2	157.1	400.3	812.2	1334.7	2011.5	2663.2
	PROLINA	47.5	163.9	412.4	826.4	1345.4	1998.1	2627.0
SE		0.4	2.9	5.7	12.8	16.9	22.1	29.5

[a,b] Means in a column within dietary crude protein or soybean meal source with no common superscripts differ significantly ($P \leq 0.05$).

[1] Initial BW measured at placement followed by feeding of the experimental diets.

[2] Use of 100 or 110 % of the NRC (1994) recommendations for the amino acids lysine, methionine, and methionine + cystine (100-NRC, 110-NRC, respectively).

[3] Represents either a commercially available soybean meal as used in industry (SBM), the commercially available soybean meal with added soybean hulls (SBM + HULLS) or Solka Floc (SBM + SF), and the experimental soybean meal from the main batch (PROLINA).

Adjusted Feed Conversion Ratio. The effects of soybean meal source and dietary amino acid levels on AdjFCR from hatch to 7, 14, 21, 28, 35 and 42 d are shown in Table 3.13. No differences in cumulative AdjFCR were observed for the birds fed the 100-NRC and 110-NRC treatments at 7 d or 14 d. However, the birds fed the 110-NRC diets had significantly better AdjFCR at 21, 28 and 35 d than those fed the 100-NRC diets. No significant differences were found among the birds fed the different soybean meal sources at 7, 14, 21, and 28 d. By 35 d, PROLINA, SBM, and SBM+SF treatments had significantly better AdjFCR than the birds fed the SBM+HULLS but this effect was not apparent at 42 d. No significant interaction between soybean meal source and amino acid levels were found.

Livability. The percentage birds alive at 7, 14, 21, 28, 35 and 42 d are shown in Table 3.14. Soybean meal source and dietary amino acid levels had no effect on livability throughout the experiment. No interactions between the treatments were found.

Carcass Yield. Effect of soybean meal source and dietary amino acids on dressed carcass, neck, fat pad, legs, thighs, wings, breast skin, Pectoralis major, Pectoralis minor, and ribs combined with back as a percentage of live BW is shown in Table 3.15. There were no effects of soybean meal source on percentage carcass composition. The birds receiving the 100-NRC treatments had a higher percentage abdominal fat pad as compared to the 110-NRC treatments. No other differences for carcass yield as a result of percentage NRC were observed. No interactions between soybean meal source and percentage NRC amino acids were observed.

Table 3.13. Effect of soybean meal source and percentage NRC (1994) recommendations for the amino acids lysine, methionine, and methionine + cystine on mortality adjusted feed conversion ratio (AdjFCR) of male broiler chickens to 7, 14, 21, 28, 35 and 42 days (d) of age in Experiment 3.2.

Dietary Amino Acids[1]	Soybean Meal Source[2]	AdjFCR					
		0-7d	0-14d	0-21d	0-28d	0-35d	0-42d
		(g:g)					
100-NRC		1.21	1.40	1.42[a]	1.55[a]	1.62[a]	1.73
110-NRC		1.18	1.38	1.39[b]	1.51[b]	1.60[b]	1.72
SE		0.02	0.02	0.02	0.02	0.02	0.01
	SBM	1.18	1.39	1.39	1.52	1.60[b]	1.72
	SBM+ HULLS	1.18	1.41	1.43	1.55	1.64[a]	1.75
	SBM+SF	1.21	1.39	1.40	1.53	1.60[b]	1.72
	PROLINA	1.21	1.37	1.39	1.52	1.60[b]	1.72
SE		0.02	0.01	0.02	0.02	0.02	0.01

[a,b] Means in a column within dietary crude protein or soybean meal source with no common superscripts differ significantly ($P \leq 0.05$).

[1] Use of 100 or 110 % of the NRC (1994) recommendations for the amino acids lysine, methionine, and methionine + cystine (100-NRC, 110-NRC, respectively).

[2] Represents either a commercially available soybean meal as used in industry (SBM), the commercially available soybean meal with added soybean hulls (SBM + HULLS) or Solka Floc (SBM + SF), and the experimental soybean meal from the main batch (PROLINA).

[3] AdjFCR = feed consumed to age / (live BW + weight of dead birds).

Table 3.14. Effect of soybean meal source and percentage NRC (1994) recommendations for the amino acids lysine, methionine and methionine + cystine on livability of male broiler chickens to 7, 14, 21, 28, 35 and 42 days (d) of age in Experiment 3.2.

Dietary Amino Acids [1]	Soybean Meal Source [2]	Livability [3]					
		0-7 d	0-14 d	0-21d	0-28 d	0-35 d	0-42 d
		(%)					
100-NRC		99.43	97.73	96.87	96.59	96.02	95.17
110-NRC		99.15	97.44	96.87	96.31	95.74	94.32
SE		0.002	0.002	0.000	0.002	0.000	0.004
	SBM	99.43	98.30	97.73	97.16	96.59	96.02
	SBM+ HULLS	98.86	97.16	96.59	96.02	95.45	94.32
	SBM+SF	100.00	98.86	98.86	98.30	97.73	97.16
	PROLINA	98.86	96.02	94.32	94.32	93.75	91.48
SE		0.010	0.010	0.010	0.003	0.000	0.010

[a,b] Means in a column within dietary crude protein or soybean meal source with no common superscript differ significantly ($P \leq 0.05$).

[1] Use of 100 or 110 % of the NRC (1994) recommendations for the amino acids lysine, methionine, and methionine + cystine (100-NRC, 110-NRC, respectively).

[2] Represents either a commercially available soybean meal as used in industry (SBM), the commercially available soybean meal with added soybean hulls (SBM + HULLS) or Solka Floc (SBM + SF), and the experimental soybean meal from the main batch (PROLINA).

[3] Percentage birds remaining alive at the respective ages.

Table 3.15. Effect of soybean meal source and percentage NRC (1994) recommendations for the amino acids lysine, methionine, and methionine + cystine on carcass yield of male broiler chickens at 42 days (d) of age in Experiment 3.2.

Dietary Amino Acids [1]	Soybean Meal Source [2]	Live BW	Dressed Carcass	Neck	Fat Pad	Legs	Thighs	Wings	Breast Skin	*Pectoralis major*	*Pectoralis minor*	Ribs and Back
		(g)	(g/100g BW)									
100-NRC		2599	72.1	3.95	1.48[a]	10.45	13.28	7.85	2.24	14.73	3.66	18.02
110-NRC		2589	71.7	3.90	1.19[b]	10.51	13.18	7.84	2.19	15.15	3.61	17.70
SE		33	0.02	0.03	0.21	0.04	0.07	0.01	0.03	0.30	0.03	0.23
	SBM	2574	71.8	3.85	1.27	10.43	13.10	7.89	2.23	14.81	3.63	18.11
	SBM+ HULLS	2654	72.2	3.75	1.42	10.58	12.99	7.82	2.36	14.93	3.64	18.01
	SBM+SF	2597	71.8	4.06	1.33	10.41	13.36	7.74	2.19	15.13	3.58	17.73
	PROLINA	2552	72.0	4.03	1.35	10.51	13.47	7.94	2.08	14.87	3.69	17.61
SE		54	0.03	0.26	0.01	0.13	0.41	0.15	0.20	0.24	0.04	0.42

[a,b] Means in a column within dietary crude protein or soybean meal source with no common superscript differ significantly ($P \leq 0.05$).

[1] Use of 100 or 110 % of the NRC (1994) recommendations for the amino acids lysine, methionine, and methionine + cystine (100-NRC, 110-NRC, respectively).

[2] Represents either a commercially available soybean meal as used in industry (SBM), the commercially available soybean meal with added soybean hulls (SBM + HULLS) or Solka Floc (SBM + SF), and the experimental soybean meal from the main batch (PROLINA).

Discussion

When interpreting the data from the two experiments in Chapter 3, it was essential to recall that the Prolina beans from the main batch were processed in a state of higher moisture resulting in a more fibrous bean meal due to inadequate removal of hulls. Therefore, appropriate direct comparisons of this data were made between PROLINA and the fiber adjusted dietary treatments, SBM+ HULLS and SBM+SF. The SBM treatment was included as a negative control, but was not thought to be realistic for a direct comparison to PROLINA.

Experiment 3.1. The data collected from the studies described in Chapter 2 supported reports that young male broiler chickens could utilize higher dietary amino acid levels, specifically amino acids lysine, methionine, and methionine + cystine, than the minimums recommended by the NRC (1994). These studies indicated that PROLINA had promise as a substitute in typical corn-soy broiler diets. We expected similar trends to be seen in the experiments of Chapter 3. In Experiment 3, neither BW nor AdjFCR evidenced the higher level of available amino acids thought to exist in Prolina soybean meal. However, the direct substitution of Prolina soybean meal into the broiler diet did not inhibit BW gain or AdjFCR with respect to the other soybean meal source treatments. What was surprising was that this main batch of Prolina soybean meal still performed as well as the commercially available soybean meal, even with a slightly different composition and containing a higher fiber dilution factor than the pilot batch used to produce the similar results in Chapter 2.

This suggested that Prolina may truly have a higher level of amino acids, which were undetected due to improper processing and the direct substitution method of inclusion in the diet.

There were no major differences in carcass yield between PROLINA and the other soybean meal treatments, which was critical in establishing it as a suitable feedstuff for broilers since the value of a broiler chicken lies in the muscle composition.

Experiment 3.1 supported our preliminary feeding trial findings that Prolina soybean meal was as good as commercial variety soybean meal in supporting normal bird performance and carcass composition when used as the major protein component in a corn-soybean meal broiler diet.

Experiment 3.2. The second feeding trial described in this chapter was designed to combine the information that was gathered in all three previous studies (Chapter 2-Experiments 2.1, 2.2 and Chapter 3-Experiment 3.1). As was the result in previous studies, Experiment 3.2 again demonstrated that the higher levels of dietary amino acids produced a higher bird BW early, but in this study the effect was not evident beyond 28 d. Insufficient ME may have been a factor in hindering maximum growth in these birds as they aged.

As expected, the effects of soybean meal source on performance were similar to those found in earlier studies. Although the PROLINA treatment did not perform better than the other soybean meal sources, no detrimental effects were found using Prolina soybean meal as a substitution in this large scale feeding trial.

Overall, these two large-scale feeding trials supported previous conclusions in that the modern commercial male broiler could utilize dietary levels of CP in excess of the minimums recommended by the NRC (1994) in order to approach their genetic potential for growth and feed conversion. Also, the Prolina cultivar soybean meal was a good substitute for standard soybean meals (~48% CP) in broiler diets; however, the higher protein thought to exist in Prolina soybean meal was not being utilized in the birds in a manner so as to significantly improve BW and AdjFCR.

As a result of these studies, it was deemed necessary to investigate the adequacy of the dietary ME that was being contributed by Prolina soybean meal, as well as the levels of ME used in the formulation of the feed. If ME were a limiting factor, this could hinder the overall performance of the bird, even with adequate CP provided. Limiting ME could be masking the true effects of Prolina soybean meal.

With these results, subsequent trials were designed to investigate the role that ME played in the dietary treatments used in the previous experiments, as well as to further examine how Prolina soybean meal and its amino acid profile compares to the commercially available soybean meal.

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CHAPTER 4

Effects of altering crude protein and metabolizable energy in diets containing Prolina high protein soybean meal on the performance of male broiler chickens

ABSTRACT. The Prolina soybean cultivar was developed through advanced plant breeding methods to possess a combination of high protein as well as reasonable oil yield and agronomic traits. Results from previous experiments where male broiler chickens were fed diets containing Prolina (Experiment 2.2, 3.1, and 3.2) demonstrated that it could be used as a poultry feedstuff in the form of oil extracted soybean meal. Initial analyses of Prolina soybean meal indicated an increased percentage CP as compared to a commercial variety of soybean meal. Analyses demonstrated that Prolina soybean meal and the commercial variety of soybean meal had similar amino acid profiles varying only slightly in some amino acids, but the Prolina soybean meal possessed a slightly higher amino acid digestibility. The present experiment with male broilers was designed to evaluate the substitution of Prolina soybean meal for the commercial variety of soybean meal in diets formulated at two CP levels (95 and 85 % of the NRC (1994) recommended values for lysine, methionine, and methionine + cystine.) These levels were then superimposed over two levels of ME (3.05 and 3.20 kcal/g ME) in corn-soy starter, grower, and finisher diets. Prolina soybean meal, a commercial variety soybean meal, or the commercial variety soybean meal amended with soybean hulls to equalize fiber, were then used as the soybean meal source in each CP and ME diet combination to create 12 dietary treatments. Bird BW and feed consumption were measured weekly and AdjFCR was calculated at weekly intervals.

The broilers in this experiment responded positively to increased levels of CP or ME. Although the effect of soybean meal source was not delineated as a main effect, it was found that at the lowest level of ME, diets containing Prolina soybean meal performed as well as diets formulated at the higher ME with any of the soybean meal sources. Therefore, Prolina may have increased value when dietary energy sources are limiting.

Introduction

Prolina, a soybean cultivar developed through advanced plant breeding to have an unusual combination of high protein as well as reasonable oil yield and agronomic traits, has demonstrated promise as a poultry feedstuff in the form of oil extracted soybean meal as discussed in Chapters 2 and 3. Prediction equations, which utilized the original analyses of whole soybeans before processing into meal, indicated that Prolina would be processed into a higher protein soybean meal when compared to a standard commercially available soybean meal has been typically used in industry. Since it was already known that Prolina soybeans had acceptable oil content, higher protein content in the soybean meal would increase the value of Prolina to soybean growers. However, as shown in Chapter 3, the proximate analyses (Table 3.1) of the Prolina soybean meal for percentage CP did not directly indicate an increased level of CP as compared to the commercially available soybean meal. Analyses of the soybean meals did not indicate any major differences in amino acid profiles (Table 3.2), however, Prolina soybean meal demonstrated higher digestibility for all amino acids analyzed as compared to the commercial variety soybean meal and a sample of the commercial variety with soybean hulls added (as per method described in Chapter 3) (Table 3.3). In theory, this higher amino acid digestibility of Prolina soybean meal should allow the amino acids to be more bioavailable to the broiler chicken (Klasing, 1998). This suggested that when provided with a marginal dietary CP level, the birds should respond to the improved digestibility of the amino acids in Prolina soybean meal. As was shown in Chapter 2, Experiment 2.1, this could be demonstrated by an improvement in BW and feed efficiency in the broilers fed the Prolina soybean meal.

The ME content in the Prolina soybean meal was also of interest. Even though the hexane method of oil extraction was used in the processing of Prolina, which is a method that has been accepted as achieving almost complete oil removal, some difference in the ME level of Prolina could potentially exist due to either residual oil or the ME value of additional non-essential amino acids. Previous experiments (Experiments 2.2, 3.1 and 3.2) were conducted by direct substitution by weight of Prolina soybean meal for the commercial variety of soybean meal. This method was based on the assumption that the ME values that were being contributed to the diet from the soybean meal sources were similar. However, laboratory analyses for ME of one sample each of Prolina soybean meal and commercial soybean meal showed that both contained similar gross energy levels, but the commercial variety had a slightly higher true metabolizable energy (TMEn) as compared to Prolina soybean meal[1] (Table 3.3). This suggested that ME could also be affecting the BW and feed efficiency responses of broilers when substituting Prolina soybean meal into broiler diets.

To further dissect the feeding value of Prolina, the following male broiler experiment was designed. Prolina soybean meal would be evaluated in place of the commercially available variety of soybean meal in diets formulated at two levels of CP (marginal and severely deficient). These dietary amino acid levels were then superimposed over diets at two levels of ME. The higher of the two ME levels was representative of the NRC recommended level for dietary ME and the other level was lower, but not unlike that used in

[1] A single sample was analyzed therefore, this is not a statistically significant statement.

commercial broiler nutrition. Therefore, the two ME levels used were representative of the range that might be encountered commercially on an international basis.

Experiment 4

Materials and Methods

Soybean Meal Processing. Prolina soybeans were grown in Northeastern North Carolina by Eure Farms and processed at the Perdue Farms Soybean Processing Plant (Cofield, NC 27922) into soybean meal as described in Chapter 3. The Prolina soybean meal and an equal amount of a commercially available soybean meal made from locally grown beans were stored in separate bins at the NCSU Poultry Science Feed Mill facility. As described in Chapter 3, appropriate fiber adjustments were made by adding soybean hulls as a fiber source to the commercial variety of soybean meal to bring both meals to the same percentage fiber content. This resulted in similar fiber dilutions for the two soybean meals.

Birds and Facility. Ross x Hubbard HiY strain broilers were feather sexed and permanently identified with neck tags at hatching. A total of 1800 male broilers were randomly distributed among 72 pens measuring 3.7 m in length and 1.2 m in width. There were 25 birds per pen in the curtain-sided house that was divided by a center feed storage area and a perpendicular central walkway into four blocks of 18 pens each. Birds were placed on previously used wood shavings that had been raked to remove any caked litter. Six 75,000 BTU space heaters were hung from the ceiling of the central walkway of the house. The heaters were directed towards eight, ¼ horsepower fans (1600 rpm and 60 cm diameter blades) directed upwards to a flat ceiling to ensure proper temperature distribution and de-stratification. Litter temperature was 32 C at placement and was decreased by 3 C weekly until 24 C was reached. Birds received 23 h of light from 0 to 7 d, 21 h through 28 d, and then natural daylight only to the end of the experiment. Supplemental light was supplied by three rows of 25-watt incandescent bulbs; one row located over the center of each pen on each side of the house and one row located over the center of the central walkway. Natural light entered the pens during daylight hours through operable translucent curtains.

Birds were provided feed and water for *ad libitum* consumption using two tube feeders and one bell waterer per pen. Supplemental feeders and waterers placed on the floor of each pen were provided from hatch to 7 d. Initially, 1135 grams of crumbled starter feed per bird was placed in each pen. At 21 d, pelleted grower feed was added on top of the remaining starter feed. Grower feed was weighed and removed at 35 d and pelleted finisher feed was added. At 49 d, access to feed was discontinued by raising the feeders 12 h prior to processing with the birds maintaining access to water.

Diets. At the starter, grower, and finisher stages, four basal corn-soy diets were formulated at 85% (85-NRC) and 95% (95-NRC) of the NRC recommended minimum values for lysine, methionine, methionine + cystine with either a calculated basal ME of 3.05 kcal ME/g (3.05 ME) or 3.20 kcal ME/g (3.20 ME) using the commercially available soybean meal as the soybean meal source. Prolina soybean meal (PROLINA), the commercial variety of soybean meal (SBM), or the commercial variety with soybean hulls added (SBM + HULLS), were then substituted by weight as the soybean meal source at each CP level and ME combination to create 12 dietary treatments in a manner similar to that described in Experiment 3.2.

Data Collection. Feed consumption and BW were measured on a pen basis at 7, 14, 21, 35 and 49 d of age. House temperature was monitored twice daily by observing eight thermometers that were located in each of the eight corner pens of the house at bird level. Dead birds were weighed and recorded twice daily. The FCR and AdjFCR were calculated at weekly intervals. At 49 d, two birds from each pen were selected to be processed for carcass analysis as described in Chapter 3. Four experienced staff conducted the cut-up and de-boning procedures.

Statistical Analysis. The experimental design was a 2 x 2 x 3 factorial with two dietary CP levels, two levels of dietary ME, and three soybean meal sources. There were 12 dietary treatments in the randomized complete block design with 72 experimental units. The four blocks consisted of 18 pens on each side of a central walkway on each end of the house with the factorial design randomly assigned within each block. There were six replicate pens per interaction mean. Statistical analysis was carried out using a randomized complete block design with the General Linear Models procedure of SAS® institute (SAS Institute, Inc., Cary, NC 1999-2001). Error was calculated from between replicate pen variation. Means were partitioned using the Duncan option. Statements of statistical significance were based on $P \leq 0.05$. No block effect was found and was not reported in Experiment 4 for brevity purposes.

Results

Diet Analyses. The ingredient compositions and percentage CP, moisture, fat, crude fiber, and ash of the starter, grower and finisher diets are shown in Tables 4.1, 4.2, 4.3, 4.4, 4.5, and 4.6, respectively. These diets were formulated on the basis of using the commercially available soybean meal and comparison between actual and analyzed values should be carried out using this as the soybean meal source. Although some analytical

Table 4.1. Compositions and proximate analyses of 85 % of NRC recommended values for the amino acids lysine, methionine, and methionine + cystine starter diets in Experiment 4.

	85-NRC Series[1]							
	3.05 kcal ME/g				3.20 kcal ME/g			
Ingredients	Constants	PROLINA[2]	SBM + HULLS[4]	SBM[3]	Constants	PROLINA[2]	SBM + HULLS[4]	SBM[3]
		(%)				(%)		
Prolina soybean meal[2]		24.60	…	…		25.00	…	…
Commercial soybean meal[3]		…	23.86	24.60		…	24.25	25.00
Soybean hulls[4]		…	0.74	…		…	0.75	…
Corn	70.01				66.80			
Poultry fat	1.14				3.94			
Dicalcium phosphate	1.82				1.82			
Limestone (calcium carbonate)	1.14				1.14			
Salt (NaCl)	0.54				0.54			
Trace mineral premix[5]	0.20				0.20			
Vitamin premix[6]	0.05				0.05			
Choline chloride (60%)	0.20				0.20			
DL-Methionine	0.13				0.14			
Coccidiostat	0.07				0.07			
Selenium premix[7]	0.10				0.10			
Total		100.0	100.0	100.0		100.0	100.0	100.0
Calculated Analyses[8]								
Metabolizable energy, kcal/g	3.05				3.20			
Crude protein, %	17.94				17.81			
Actual Analyses[9]								
Crude protein, %		18.25	17.89	17.94		19.53	18.68	19.67
Moisture, %		12.68	12.37	12.30		12.89	12.45	12.75
Fat, %		4.06	4.19	3.87		5.90	5.55	5.72
Fiber, %		2.90	2.60	2.70		3.00	2.90	2.60
Ash, %		4.94	4.96	5.01		4.93	4.48	4.84

[1] Formulated at 85% of the NRC (1994) recommendations for the amino acids lysine, methionine, and methionine + cystine (85-NRC).

[2] The experimental soybean meal from the main batch was added to constant ingredients by weight to create the dietary treatment, PROLINA.

[3] A commercial variety soybean meal typically used in industry was added to the constant ingredients to create the dietary treatment SBM.

[4] Soybean hulls as typically used in industry were added to commercial variety soybean meal as a fiber source by weight. This combination was added to constants to create the SBM +HULLS dietary treatment.

[5] Supplied per kg diet: manganese 120 mg, zinc 120 mg, iron 80 mg, copper 10 mg, iodine 2.5 mg, and cobalt 1.0 mg.

[6] Supplied per kg diet: retinol 6600 IU, cholecalciferol 2000 IU, vitamin E 33 IU, vitamin B_{12} 19.8 ug, riboflavin 6.6 mg, niacin 55 mg, pantothenic acid 11 mg, vitamin K 2 mg, folic acid 1.1 mg, thiamine 2 mg, pyridoxine 4 mg, and biotin 126 ug.

[7] Selenium premix provided 0.10 mg selenium/kg of diet.

[8] Calculated values from linear programming feed formulation method.

[9] Proximate analyses performed by Woodson-Tenent Laboratories, Goldston, NC 27252.

Table 4.2. Compositions and proximate analyses of 85 % of NRC recommended values for the amino acids lysine, methionine, and methionine + cystine grower diets in Experiment 4.

	85-NRC Series[1]							
	3.05 kcal ME/g				3.20 kcal ME/g			
Ingredients	Constants	PROLINA[2]	SBM + HULLS[4]	SBM[3]	Constants	PROLINA[2]	SBM + HULLS[4]	SBM[3]
	(%)				(%)			
Prolina soybean meal[2]		21.50	…	…		22.00	…	…
Commercial soybean meal[3]		…	20.85	21.50		…	21.34	22.00
Soybean hulls[4]		…	0.65	…		…	0.66	…
Corn	73.78				70.45			
Poultry fat	0.60				3.43			
Dicalcium phosphate	1.84				1.85			
Limestone (calcium carbonate)	1.15				1.14			
Salt (NaCl)	0.49				0.49			
Trace mineral premix[5]	0.20				0.20			
Vitamin premix[6]	0.05				0.05			
Choline chloride (60%)	0.20				0.20			
DL-Methionine	0.03				0.03			
Coccidiostat	0.07				0.07			
Selenium premix[7]	0.10				0.10			
Total		100.0	100.0	100.0		100.0	100.0	100.0
Calculated Analyses[8]								
Metabolizable energy, kcal/g	3.05				3.20			
Crude protein, %	16.72				16.64			
Actual Analyses[9]								
Crude protein, %		17.84	18.10	17.82		17.43	17.19	17.35
Moisture, %		13.08	13.09	13.21		12.50	12.50	12.39
Fat, %		3.22	3.27	3.77		5.77	6.12	5.42
Fiber, %		2.80	2.00	2.10		1.80	2.00	2.10
Ash, %		5.33	5.01	5.19		5.36	5.19	5.36

[1] Formulated at 85% of the NRC (1994) recommendations for the amino acids lysine, methionine, and methionine + cystine (85-NRC).

[2] The experimental soybean meal from the main batch was added to constant ingredients by weight to create the dietary treatment, PROLINA.

[3] A commercial variety soybean meal typically used in industry was added to the constant ingredients to create the dietary treatment SBM.

[4] Soybean hulls as typically used in industry were added to commercial variety soybean meal as a fiber source by weight. This combination was added to constants to create the SBM +HULLS dietary treatment.

[5] Supplied per kg diet: manganese 120 mg, zinc 120 mg, iron 80 mg, copper 10 mg, iodine 2.5 mg, and cobalt 1.0 mg.

[6] Supplied per kg diet: retinol 6600 IU, cholecalciferol 2000 IU, vitamin E 33 IU, vitamin B_{12} 19.8 ug, riboflavin 6.6 mg, niacin 55 mg, pantothenic acid 11 mg, vitamin K 2 mg, folic acid 1.1 mg, thiamine 2 mg, pyridoxine 4 mg, and biotin 126 ug.

[7] Selenium premix provided 0.10 mg selenium/kg of diet.

[8] Calculated values from linear programming feed formulation method.

[9] Proximate analyses performed by Woodson-Tenent Laboratories, Goldston, NC 27252.

Table 4.3. Compositions and proximate analyses of 85 % of NRC recommended values for the amino acids lysine, methionine, and methionine + cystine finisher diets in Experiment 4.

	85-NRC Series[1]							
	3.05 kcal ME/g				3.20 kcal ME/g			
Ingredients	Constants	PROLINA[2]	SBM + HULLS[4]	SBM[3]	Constants	PROLINA[2]	SBM + HULLS[4]	SBM[3]
	(%)				(%)			
Prolina soybean meal[2]		16.82	…	…		17.04	…	…
Commercial soybean meal[3]		…	16.31	16.82		…	16.53	17.04
Soybean hulls[4]		…	0.51	…		…	0.51	…
Corn	78.84				76.18			
Poultry fat	0.19				2.62			
Dicalcium phosphate	1.87				1.88			
Limestone (calcium carbonate)	1.15				1.15			
Salt (NaCl)	0.46				0.46			
Trace mineral premix[5]	0.20				0.20			
Vitamin premix[6]	0.05				0.05			
Choline chloride (60%)	0.20				0.20			
DL-Methionine	0.01				0.02			
Coccidiostat	0.07				0.07			
Selenium premix[7]	0.10				0.10			
Total		100.0	100.0	100.0		100.0	100.0	100.0
Calculated Analyses[8]								
Metabolizable energy, kcal/g	3.05				3.20			
Crude protein, %	14.61				14.52			
Actual Analyses[9]								
Crude protein, %		14.79	14.65	15.43		14.71	15.08	15.14
Moisture, %		12.77	12.35	12.43		11.62	11.76	12.20
Fat, %		2.89	3.11	3.44		4.96	5.46	5.78
Fiber, %		1.90	1.90	2.00		2.00	1.90	1.98
Ash, %		4.95	4.93	4.63		4.95	4.81	4.73

[1] Formulated at 85% of the NRC (1994) recommendations for the amino acids lysine, methionine, and methionine + cystine (85-NRC).

[2] The experimental soybean meal from the main batch was added to constant ingredients by weight to create the dietary treatment, PROLINA.

[3] A commercial variety soybean meal typically used in industry was added to the constant ingredients to create the dietary treatment SBM.

[4] Soybean hulls as typically used in industry were added to commercial variety soybean meal as a fiber source by weight. This combination was added to constants to create the SBM +HULLS dietary treatment.

[5] Supplied per kg diet: manganese 120 mg, zinc 120 mg, iron 80 mg, copper 10 mg, iodine 2.5 mg, and cobalt 1.0 mg.

[6] Supplied per kg diet: retinol 6600 IU, cholecalciferol 2000 IU, vitamin E 33 IU, vitamin B_{12} 19.8 ug, riboflavin 6.6 mg, niacin 55 mg, pantothenic acid 11 mg, vitamin K 2 mg, folic acid 1.1 mg, thiamine 2 mg, pyridoxine 4 mg, and biotin 126 ug.

[7] Selenium premix provided 0.10 mg selenium/kg of diet.

[8] Calculated values from linear programming feed formulation method.

[9] Proximate analyses performed by Woodson-Tenent Laboratories, Goldston, NC 27252.

Table 4.4. Compositions and proximate analyses of 95 % of NRC recommended values for the amino acids lysine, methionine, and methionine + cystine starter diets in Experiment 4.

	95-NRC Series[1]							
	3.05 kcal ME/g				3.20 kcal ME/g			
Ingredients	Constants	PROLINA[2]	SBM + HULLS[4]	SBM[3]	Constants	PROLINA[2]	SBM + HULLS[4]	SBM[3]
	(%)				(%)			
Prolina soybean meal[2]		29.80	…	…		30.40	…	…
Commercial soybean meal[3]		…	28.91	29.80		…	29.49	30.40
Soybean hulls[4]		…	0.89	…		…	0.91	…
Corn	64.09				60.44			
Poultry fat	1.98				5.04			
Dicalcium phosphate	1.78				1.00			
Limestone (calcium carbonate)	1.14				1.78			
Salt (NaCl)	0.54				0.54			
Trace mineral premix[5]	0.20				0.20			
Vitamin premix[6]	0.05				0.05			
Choline chloride (60%)	0.20				0.20			
DL-Methionine	0.05				0.18			
Coccidiostat	0.07				0.07			
Selenium premix[7]	0.10				0.10			
Total		100.0	100.0	100.0		100.0	100.0	100.0
Calculated Analyses[8]								
Metabolizable energy, kcal/g	3.05				3.20			
Crude protein, %	19.94				19.92			
Actual Analyses[9]								
Crude protein, %		19.27	19.97	18.66		20.96	20.06	20.58
Moisture, %		12.94	12.45	12.93		12.48	12.62	12.42
Fat, %		4.35	4.41	4.13		6.73	6.01	6.90
Fiber, %		3.40	2.80	2.50		3.10	2.70	2.90
Ash, %		4.90	5.27	5.01		5.31	5.53	5.14

[1] Formulated at 95% of the NRC (1994) recommendations for the amino acids lysine, methionine, and methionine + cystine (95-NRC).

[2] The experimental soybean meal from the main batch was added to constant ingredients by weight to create the dietary treatment, PROLINA.

[3] A commercial variety soybean meal typically used in industry was added to the constant ingredients to create the dietary treatment SBM.

[4] Soybean hulls as typically used in industry were added to commercial variety soybean meal as a fiber source by weight. This combination was added to constants to create the SBM +HULLS dietary treatment.

[5] Supplied per kg diet: manganese 120 mg, zinc 120 mg, iron 80 mg, copper 10 mg, iodine 2.5 mg, and cobalt 1.0 mg.

[6] Supplied per kg diet: retinol 6600 IU, cholecalciferol 2000 IU, vitamin E 33 IU, vitamin B_{12} 19.8 ug, riboflavin 6.6 mg, niacin 55 mg, pantothenic acid 11 mg, vitamin K 2 mg, folic acid 1.1 mg, thiamine 2 mg, pyridoxine 4 mg, and biotin 126 ug.

[7] Selenium premix provided 0.10 mg selenium/kg of diet.

[8] Calculated values from linear programming feed formulation method.

[9] Proximate analyses performed by Woodson-Tenent Laboratories, Goldston, NC 27252.

Table 4.5. Compositions and proximate analyses of 95 % of NRC recommended values for the amino acids lysine, methionine, and methionine + cystine grower diets in Experiment 4.

	95-NRC Series[1]							
	3.05 kcal ME/g				3.20 kcal ME/g			
Ingredients	Constants	PROLINA[2]	SBM + HULLS[4]	SBM[3]	Constants	PROLINA[2]	SBM + HULLS[4]	SBM[3]
	(%)				(%)			
Prolina soybean meal[2]		26.20	…	…		26.50	…	…
Commercial soybean meal[3]		…	25.41	26.20		…	25.70	26.50
Soybean hulls[4]		…	0.79	…		…	0.80	…
Corn	68.35				65.31			
Poultry fat	1.35				4.15			
Dicalcium phosphate	1.81				1.82			
Limestone (calcium carbonate)	1.14				1.13			
Salt (NaCl)	0.49				0.49			
Trace mineral premix[5]	0.20				0.20			
Vitamin premix[6]	0.05				0.05			
Choline chloride (60%)	0.20				0.20			
DL-Methionine	0.05				0.05			
Coccidiostat	0.07				0.07			
Selenium premix[7]	0.10				0.10			
Total		100.0	100.0	100.0		100.0	100.0	100.0
Calculated Analyses[8]								
Metabolizable energy, kcal/g	3.05				3.20			
Crude protein, %	18.48				18.34			
Actual Analyses[9]								
Crude protein, %		20.37	18.89	19.84		19.49	18.95	18.92
Moisture, %		12.47	13.28	13.30		12.80	12.19	12.37
Fat, %		4.14	3.52	5.57		7.07	6.76	3.16
Fiber, %		2.20	1.90	1.90		2.30	2.10	1.90
Ash, %		5.37	5.39	5.52		5.14	5.61	5.71

[1] Formulated at 95% of the NRC (1994) recommendations for the amino acids lysine, methionine, and methionine + cystine (95-NRC).

[2] The experimental soybean meal from the main batch was added to constant ingredients by weight to create the dietary treatment, PROLINA.

[3] A commercial variety soybean meal typically used in industry was added to the constant ingredients to create the dietary treatment SBM.

[4] Soybean hulls as typically used in industry were added to commercial variety soybean meal as a fiber source by weight. This combination was added to constants to create the SBM +HULLS dietary treatment.

[5] Supplied per kg diet: manganese 120 mg, zinc 120 mg, iron 80 mg, copper 10 mg, iodine 2.5 mg, and cobalt 1.0 mg.

[6] Supplied per kg diet: retinol 6600 IU, cholecalciferol 2000 IU, vitamin E 33 IU, vitamin B_{12} 19.8 ug, riboflavin 6.6 mg, niacin 55 mg, pantothenic acid 11 mg, vitamin K 2 mg, folic acid 1.1 mg, thiamine 2 mg, pyridoxine 4 mg, and biotin 126 ug.

[7] Selenium premix provided 0.10 mg selenium/kg of diet.

[8] Calculated values from linear programming feed formulation method.

[9] Proximate analyses performed by Woodson-Tenent Laboratories, Goldston, NC 27252.

Table 4.6. Compositions and proximate analyses of 95 % of NRC recommended values for the amino acids lysine, methionine, and methionine + cystine finisher diets in Experiment 4.

	95-NRC Series[1]							
	3.05 kcal ME/g				3.20 kcal ME/g			
Ingredients	Constants	PROLINA[2]	SBM + HULLS[4]	SBM[3]	Constants	PROLINA[2]	SBM + HULLS[4]	SBM[3]
		(%)				(%)		
Prolina soybean meal[2]		20.12	…	…		20.34	…	…
Commercial soybean meal[3]		…	19.52	20.12		…	19.73	20.34
Soybean hulls[4]		…	0.60	…		…	0.61	…
Corn	75.00				71.85			
Poultry fat	0.73				3.15			
Dicalcium phosphate	1.85				1.86			
Limestone (calcium carbonate)	1.15				1.14			
Salt (NaCl)	0.46				0.46			
Trace mineral premix[5]	0.20				0.20			
Vitamin premix[6]	0.05				0.05			
Choline chloride (60%)	0.20				0.20			
DL-Methionine	0.03				0.03			
Coccidiostat	0.07				0.07			
Selenium premix[7]	0.10				0.10			
Total		100.0	100.0	100.0		100.0	100.0	100.0
Calculated Analyses[8]								
Metabolizable energy, kcal/g	3.05				3.20			
Crude protein, %	15.92				15.82			
Actual Analyses[9]								
Crude protein, %		15.82	16.40	16.54		16.09	16.45	15.24
Moisture, %		12.31	12.30	12.19		12.34	11.61	12.34
Fat, %		3.61	3.21	4.83		5.79	6.08	3.52
Fiber, %		1.80	2.00	2.20		2.00	2.00	2.20
Ash, %		5.03	5.21	5.11		4.72	4.54	5.04

[1] Formulated at 95% of the NRC (1994) recommendations for the amino acids lysine, methionine, and methionine + cystine (95-NRC).

[2] The experimental soybean meal from the main batch was added to constant ingredients by weight to create the dietary treatment, PROLINA.

[3] A commercial variety soybean meal typically used in industry was added to the constant ingredients to create the dietary treatment SBM.

[4] Soybean hulls as typically used in industry were added to commercial variety soybean meal as a fiber source by weight. This combination was added to constants to create the SBM +HULLS dietary treatment.

[5] Supplied per kg diet: manganese 120 mg, zinc 120 mg, iron 80 mg, copper 10 mg, iodine 2.5 mg, and cobalt 1.0 mg.

[6] Supplied per kg diet: retinol 6600 IU, cholecalciferol 2000 IU, vitamin E 33 IU, vitamin B_{12} 19.8 ug, riboflavin 6.6 mg, niacin 55 mg, pantothenic acid 11 mg, vitamin K 2 mg, folic acid 1.1 mg, thiamine 2 mg, pyridoxine 4 mg, and biotin 126 ug.

[7] Selenium premix provided 0.10 mg selenium/kg of diet.

[8] Calculated values from linear programming feed formulation method.

[9] Proximate analyses performed by Woodson-Tenent Laboratories, Goldston, NC 27252.

variation exists, results of the analyses were within expected range supporting proper formulation of the diet. The other soybean meal sources were substituted by weight and calculated values were provided as a reference. However, these values did describe some of the expected nutritional variation that was thought to exist between the soybean meal sources.

Body Weight. The effects on BW of CP, ME and soybean meal source are shown in Table 4.7. The birds that were fed the 95-NRC dietary treatments exhibited a significantly greater BW than those fed the 85-NRC treatments throughout the experiment. The dietary 3.20 ME diets produced significantly heavier birds at 21 d and 49 d as compared to those fed the 3.05 ME treatments. No delineation of the effect of soybean meal source on BW was found. However, broilers fed the 3.05-ME with PROLINA diets were significantly heavier than the 3.05 ME with SBM + HULLS and not different than the other treatments even when formulated at the higher energy level.

Adjusted Feed Conversion Ratio. Table 4.8 shows the cumulative AdjFCR to 7, 14, 21, 35, and 49 d. The 95-NRC dietary treatment had a significantly improved AdjFCR as compared to the 85-NRC diet throughout the trial. The 3.20 ME had a significantly improved AdjFCR at 14, 21, 35 and 49 d as compared to the 3.05 ME treatments. However, there was no effect of soybean meal source on AdjFCR throughout the experiment.

For the interaction of CP and ME level, it was found that at 35 d birds consuming the 95-NRC diets, regardless of ME, exhibited an improved AdjFCR as compared to the other treatments. The 85-NRC and 3.20 ME diet series had significantly better AdjFCR as compared to the 85-NRC and 3.05 ME dietary treatments.

Table 4.7. Effect of dietary crude protein (methionine, methionine + cystine, and lysine), dietary metabolizable energy level, and soybean meal source on body weight (BW) of male broiler chickens at 7, 14, 21, 35 and 49 days (d) of age in Experiment 4.

Dietary Crude Protein Level[1]	Dietary Metabolizable Energy	Soybean Meal Source[2]	BW					
			Initial[3]	7 d	14 d	21 d	35 d	49 d
	(kcal/g)		(%)					
85-NRC			39.5	119.5[b]	283.5[b]	569.7[b]	1428.5[b]	2536.6[b]
95-NRC			39.4	136.0[a]	343.2[a]	705.5[a]	1796.6[a]	3167.2[a]
	SE		0.1	11.6	42.6	96.0	260.3	446.9
	3.05		39.3	126.8	309.9	628.9[b]	1602.3	2823.1[b]
	3.20		39.6	128.6	316.3	646.2[a]	1622.8	2880.8[a]
	SE		0.2	1.3	4.5	12.2	14.5	40.8
		SBM	39.3	126.5	310.0	631.3	1605.1	2872.4
		SBM + HULLS	39.2	126.9	312.6	636.5	1608.4	2829.0
		PROLINA	39.7	129.8	316.7	644.8	1624.2	2854.5
	SE		0.2	1.9	3.4	6.8	10.2	21.8
85-NRC		SBM	39.2	119.4	281.2	559.7	1410.4	2542.6
85-NRC		SBM+ HULLS	39.7	117.3	280.4	570.6	1432.0	2526.6
85-NRC		PROLINA	39.6	121.7	287.4	578.7	1443.3	2540.7
95-NRC		SBM	39.3	133.5	338.9	702.9	1799.9	3202.1
95-NRC		SBM+ HULLS	39.3	136.4	344.7	702.3	1784.8	3131.4
95-NRC		PROLINA	39.7	138.0	346.1	710.9	1805.2	3168.3
	SE		0.2	1.8	2.5	4.6	13.5	19.4
	3.05	SBM	39.1	124.5	303.3	614.9	1576.5	2815.2[bcd]
	3.05	SBM+ HULLS	39.4	127.2	312.1	630.8	1598.7	2780.8[d]
	3.05	PROLINA	39.5	128.9	314.4	640.9	1631.8	2873.4[abc]
	3.20	SBM	39.4	128.4	316.8	647.7	1633.8	2929.6[a]
	3.20	SBM+ HULLS	39.6	126.6	313.0	642.1	1618.0	2877.2[ab]
	3.20	PROLINA	39.8	130.8	319.1	648.7	1616.7	2835.6[bcd]
	SE		0.1	1.6	4.6	9.6	25.6	58.8
85-NRC	3.05		39.2	117.3	275.5[c]	551.1[c]	1396.0[c]	2472.8[c]
85-NRC	3.20		39.7	121.7	290.5[b]	588.2[b]	1461.1[b]	2600.6[b]
95-NRC	3.05		39.4	136.4	344.4[a]	706.6[a]	1808.7[a]	3173.5[a]
95-NRC	3.20		39.5	135.5	342.1[a]	704.1[a]	1784.6[a]	3160.0[a]
	SE		0.8	2.7	8.7	19.8	44.6	70.2

[a,b,c,d] Means in a column with no common superscripts differ significantly.

[1] 85 or 95 % of the NRC (1994) recommendations for the amino acids lysine, methionine, and methionine + cystine (85-NRC and 95-NRC, respectively).

[2] Represents either commercially available soybean meal as used in industry (SBM), the commercially available soybean meal with added soybean hulls (SBM+HULLS), and the experimental soybean meal from the main batch (PROLINA).

[3] Initial BW measured at placement.

Table 4.8. **Effect of dietary amino acid level (methionine, methionine + cystine, and lysine), dietary metabolizable energy level, and soybean meal source on mortality adjusted feed conversion ratio (AdjFCR) of male broiler chickens to 7, 14, 21, 35 and 49 days (d) of age in Experiment 4.**

Dietary Crude Protein Level [1]	Dietary Metabolizable Energy	Soybean Meal Source [2]	AdjFCR [3]				
			0-7 d	0-14 d	0-21 d	0-35 d	0-49 d
	(kcal/g)				(%)		
85-NRC			1.29[a]	1.47[a]	1.56[a]	1.74[a]	2.22[a]
95-NRC			1.20[b]	1.35[b]	1.45[b]	1.61[b]	1.94[b]
	SE		0.06	0.09	0.08	0.09	0.20
	3.05		1.25	1.43[a]	1.52[a]	1.69[a]	2.11[a]
	3.20		1.24	1.39[b]	1.49[b]	1.66[b]	2.04[b]
	SE		0.01	0.03	0.02	0.02	0.05
		SBM	1.26	1.42	1.51	1.67	2.06
		SBM + HULLS	1.24	1.41	1.51	1.69	2.10
		PROLINA	1.23	1.40	1.49	1.67	2.08
	SE		0.01	0.01	0.01	0.02	0.02
85-NRC		SBM	1.33	1.50	1.59	1.75	2.19
85-NRC		SBM+ HULLS	1.28	1.47	1.55	1.75	2.25
85-NRC		PROLINA	1.25	1.45	1.54	1.73	2.22
95-NRC		SBM	1.19	1.35	1.44	1.59	1.92
95-NRC		SBM+ HULLS	1.20	1.34	1.47	1.63	1.96
95-NRC		PROLINA	1.20	1.35	1.45	1.62	1.94
	SE		0.03	0.02	0.03	0.01	0.01
	3.05	SBM	1.29	1.45	1.53	1.68	2.07
	3.05	SBM+ HULLS	1.25	1.43	1.53	1.71	2.16
	3.05	PROLINA	1.21	1.41	1.51	1.69	2.11
	3.20	SBM	1.23	1.39	1.50	1.67	2.04
	3.20	SBM+ HULLS	1.23	1.39	1.49	1.66	2.05
	3.20	PROLINA	1.25	1.40	1.48	1.66	2.05
	SE		0.04	0.02	0.01	0.02	0.03
85-NRC	3.05		1.30	1.50	1.58	1.77[a]	2.27
85-NRC	3.20		1.28	1.45	1.54	1.72[b]	2.17
95-NRC	3.05		1.20	1.36	1.46	1.62[c]	1.96
95-NRC	3.20		1.20	1.34	1.44	1.61[c]	1.92
	SE		0.01	0.02	0.01	0.01	0.03

[a,b,c] Means in a column with no common superscripts differ significantly.

[1] 85 or 95 % of the NRC (1994) recommendations for the amino acids lysine, methionine, and methionine + cystine (85-NRC and 95-NRC, respectively).

[2] Represents either commercial soybean meal as used in industry (SBM), the commercial soybean meal with added soybean hulls (SBM+HULLS), and the experimental soybean meal from the main batch (PROLINA).

[3] AdjFCR=Feed consumed to age / (live body weight + weight of dead birds)

Livability. The effect of CP, ME, and soybean meal source on percentage birds alive to 7, 14, 21, 35 and 49 d is shown in Table 4.9. The birds receiving the 95-NRC treatments had significantly improved livability to 21 d, but not thereafter, as compared to the 85-NRC. No effects of dietary ME on livability were found. The birds receiving the PROLINA soybean meal source had improved overall livability to 49 d, as compared to the SBM + HULLS treatments with the SBM treatment intermediate. For the interaction of CP and soybean meal source it was found at 21 d that the birds on the 95-NRC and PROLINA, 95-NRC and SBM, 95-NRC and SBM + HULLS, and the 85-NRC and PROLINA had better livability than those receiving the 85-NRC and SBM treatments with the 85-NRC and SBM + HULLS intermediate. No other significant interactions were found.

Carcass Yield. The effect of CP, ME, and soybean meal source on carcass yield is shown in Table 4.10. Birds receiving the 95-NRC treatments had a higher live BW and percentage dressed carcass, neck, *Pectoralis major*, and *Pectoralis minor* compared to those fed the 85-NRC treatments. Birds receiving the 3.20 ME diets had a higher percentage abdominal fat pad as compared to those on the 3.05 ME treatments. No effect of soybean meal source on carcass yield was found.

Discussion

In Chapters 2 and 3 experiments were designed to establish BW and feed efficiency responses for broilers fed varying levels of CP (lysine, methionine, and methionine + cystine based) using Prolina soybean meal as a substitute for a commercially available soybean meal. It became evident through the results of these prior experiments that it was difficult to delineate a protein effect with regards to soybean meal source. Therefore, in order to

Table 4.9. Effect of dietary amino acids, dietary metabolizable energy and soybean meal source on livability of male broiler chickens to 7, 14, 21, 35 and 49 days (d) of age in Experiment 4.

Dietary Crude Protein Level [1]	Dietary Metabolizable Energy	Soybean Meal Source [3]	Livability[3]				
			0-7 d	0-14 d	0-21 d	0-35 d	0-49 d
	(kcal/g)				(%)		
85-NRC			98.89[b]	98.44[b]	97.89[b]	97.00	95.67
95-NRC			99.89[a]	99.56[a]	99.22[a]	98.44	96.56
	SE		0.71	0.78	0.94	1.02	0.63
	3.05		99.11	98.89	98.44	97.67	95.78
	3.20		99.67	99.11	98.67	97.78	96.44
	SE		0.40	0.16	0.16	0.08	0.47
		SBM	99.33	99.00	98.83	97.33	94.33[ab]
		SBM + HULLS	99.33	99.00	98.83	97.33	94.33[a]
		PROLINA	99.67	99.17	99.00	98.83	98.00[b]
	SE		0.25	0.17	0.63	0.98	1.84
85-NRC		SBM	98.33	97.67	96.33[b]	95.33	95.00
85-NRC		SBM+ HULLS	98.67	98.33	98.00[ab]	96.67	94.00
85-NRC		PROLINA	99.67	99.33	99.33[a]	99.00	98.00
95-NRC		SBM	100.00	100.00	99.33[a]	98.67	97.00
95-NRC		SBM+ HULLS	100.00	99.67	99.67[a]	98.00	94.67
95-NRC		PROLINA	99.67	99.00	98.67[a]	98.67	98.00
	SE		0.62	0.95	1.31	1.30	0.72
	3.05	SBM	98.67	98.67	97.67	96.67	95.00
	3.05	SBM+ HULLS	98.67	98.67	98.67	97.33	94.00
	3.05	PROLINA	100.00	99.33	99.00	99.00	98.33
	3.20	SBM	99.67	99.00	98.00	97.33	97.00
	3.20	SBM+ HULLS	100.00	99.33	99.00	97.33	94.67
	3.20	PROLINA	99.33	99.00	99.00	98.67	97.67
	SE		0.76	0.36	0.14	0.36	0.94
85-NRC	3.05		98.20	98.00	97.80	96.70	95.10
85-NRC	3.20		99.56	98.89	98.00	97.33	96.22
95-NRC	3.05		100.00	99.78	99.11	98.67	96.44
95-NRC	3.20		99.78	99.33	99.33	98.22	96.67
	SE		0.78	0.67	0.71	0.56	0.44

[a,b,c] Means in a column with no common superscripts differ significantly.

[1] 85 or 95 % of the NRC (1994) recommendations for the amino acids lysine, methionine, and methionine + cystine (85-NRC and 95-NRC, respectively).

[2] Represents either commercial soybean meal as used in industry (SBM), the commercial soybean meal with added soybean hulls (SBM+HULLS), and the experimental soybean meal from the main batch (PROLINA).

[3] Percentage birds remaining alive at the respective ages.

Table 4.10. Effect of dietary amino acids, dietary metabolizable energy level, and soybean meal source on carcass yield of male broiler chickens at 49 days (d) of age in Experiment 4.

Dietary Crude Protein Level[1]	Metabolizable Energy	Soybean Meal Source[2]	Live BW	Dressed Carcass	Neck	Fat Pad	Legs	Thighs	Wings	Breast Skin	*Pectoralis major*	*Pectoralis minor*	Ribs and Back
	(kcal/g)		(g)	(g/100g BW)									
85-NRC			2660[b]	69.2[b]	3.9[a]	1.6	10.9	13.7	7.5	2.1	12.2[b]	3.3[b]	18.1
95-NRC			3130[a]	72.9[a]	3.5[b]	1.4	10.8	13.6	7.5	2.2	15.2[a]	3.8[a]	19.6
	SE		332	2.60	0.24	0.10	0.12	0.08	0.02	0.08	2.13	0.32	1.04
	3.05		2896	70.7	3.7	1.4[b]	10.9	13.7	7.4	2.1	13.7	3.5	19.6
	3.20		2893	71.5	3.6	1.6[a]	10.8	13.7	7.6	2.1	13.7	3.5	18.0
	SE		2	0.56	0.06	0.16	0.09	0.03	0.09	0.01	0.06	0.01	1.12
		SBM	2929	70.9	3.6	1.7	10.8	13.6	7.5	2.1	13.9	3.5	18.3
		SBM + HULLS	2813	70.8	3.8	1.4	10.9	13.7	7.5	2.1	13.4	3.5	17.9
		PROLINA	2942	71.6	3.7	1.5	10.8	13.7	7.5	2.2	13.9	3.5	20.3
	SE		14	0.43	0.07	0.14	0.07	0.07	0.03	0.07	0.29	0.01	1.29

[a,b,c] Means in a column with no common superscripts differ significantly.

[1] 85 or 95 % of the NRC (1994) recommendations for the amino acids lysine, methionine, and methionine + cystine (85-NRC and 95 NRC, respectively).

[2] Represents either commercially available soybean meal as used in industry (SBM), the commercial soybean meal with added soybean Hulls (SBM+HULLS), and the experimental soybean meal from the main batch (PROLINA).

Table 4.10 continued. Effect of dietary amino acids, dietary metabolizable energy level, and soybean meal source on carcass yield of male broiler chickens at 49 days (d) of age in Experiment 4.

Dietary Crude Protein Level [1]	Metabolizable Energy	Soybean Meal Source [2]	Live BW	Dressed Carcass	Neck	Fat Pad	Legs	Thighs	Wings	Breast Skin	*Pectoralis major*	*Pectoralis minor*	Ribs and Back
	(kcal/g)		(g)	(g/100g BW)									
85-NRC		SBM	2680	68.5	3.8[ab]	1.7	11.0	13.5	7.6	2.0	12.1	3.3	18.5
85-NRC		SBM+ HULLS	2517	68.9	4.1[a]	1.4	11.0	13.9	7.4	2.0	12.0	3.3	17.5
85-NRC		PROLINA	2783	70.3	3.8[abc]	1.7	10.8	13.8	7.5	2.2	12.5	3.3	18.3
95-NRC		SBM	3178	73.2	3.4[c]	1.6	10.6	13.7	7.4	2.2	15.6	3.7	18.0
95-NRC		SBM+ HULLS	3109	72.7	3.5[c]	1.4	10.8	13.6	7.6	2.1	14.7	3.8	18.3
95-NRC		PROLINA	3102	72.8	3.7[abc]	1.3	10.9	13.6	7.6	2.2	15.3	3.8	22.3
	SE		98.0	0.80	0.21	0.13	0.19	0.16	0.11	0.04	0.30	0.03	1.64
	3.05	SBM	2904	69.9	3.6	1.6	10.9	13.6	7.4	2.1[ab]	13.7	3.5	18.4
	3.05	SBM+ HULLS	2804	70.7	3.6	1.3	10.9	13.7	7.3	1.9[b]	13.4	3.6	18.1
	3.05	PROLINA	2981	71.4	3.7	1.3	10.9	13.7	7.5	2.3[a]	14.0	3.5	22.4
	3.20	SBM	2954	71.8	3.7	1.2	10.7	13.6	7.5	2.2[ab]	14.1	3.6	18.1
	3.20	SBM+ HULLS	2822	70.8	3.8	1.5	10.9	13.8	7.6	2.2[ab]	13.4	3.5	17.7
	3.20	PROLINA	2904	71.7	3.8	1.7	10.8	13.7	7.5	2.1[ab]	13.8	3.5	18.2
	SE		47	0.72	0.05	0.09	0.07	0.02	0.11	0.19	0.21	0.09	1.56
85-NRC	3.05		2654	73.2	3.9	1.4	10.9	13.7	7.4	2.0	12.1	3.3	18.2
85-NRC	3.20		2665	70.0	3.9	1.7	10.9	13.7	7.6	2.1	12.3	3.3	18.0
95-NRC	3.05		3138	72.9	3.5	1.4	10.9	13.6	7.5	2.2	15.2	3.8	21.0
95-NRC	3.20		3121	72.9	3.6	1.5	10.6	13.7	7.5	2.1	15.2	3.7	18.1
	SE		13.9	0.81	0.04	0.07	0.02	0.02	0.09	0.10	0.05	0.03	1.34

[a,b,c] Means in a column with no common superscripts differ significantly.

[1] 85 or 95 % of the NRC (1994) recommendations for the amino acids lysine, methionine, and methionine + cystine (85-NRC and 95-NRC, respectively).

[2]Represents either commercially available soybean meal as used in industry (SBM), the commercial soybean meal with added soybean hulls (SBM+HULLS), and the experimental soybean meal from the main batch (PROLINA).

demonstrate a response as a result of feeding Prolina soybean meal, it was thought necessary to formulate Experiment 4 diets at a more deficient dietary CP value. Verification of the deficient nature of the diets was evident by the broiler BW response. As is shown in Figure 4.1, the relatively higher dietary CP level (95-NRC) produced an increased BW as compared to the more deficient CP level (85-NRC) as early as 7 d of age and continued throughout the experiment. The ability of increased dietary CP to improve the early growth and BW of the broiler has been well documented (Klasing, 1998) and similar growth responses to increased dietary CP levels were seen in Experiments 2.1, 3.1, and 3.2.

The broiler BW response as an effect of altering ME level (3.05 ME versus 3.20 ME) is shown in Figure 4.1 and demonstrates that the amount of ME in the diet did not result in differences in BW until 21 d of age. By 49 d the birds fed the higher ME diets (3.20 ME) were significantly larger than those fed the lower ME (3.05 ME). These results suggested that ME levels did not have detectable effects on early growth, but could be a limiting factor on growth as the bird aged and the daily ME requirements increased.

Since previous Experiments 2.2, 3.1, and 3.2 failed to delineate an effect of soybean meal source on BW, it was not surprising that the soybean meal sources in this experiment did not affect broiler BW as shown in Figure 4.2.

Figure 4.3 delineates the effects of the CP and ME interaction on broiler BW. Although there was a large BW difference between the high and low CP regardless of ME, it was interesting to note that the birds fed 95-NRC treatments, at the two levels of ME were not different. However, at the 85-NRC level, the higher ME (3.20 ME) is significantly heavier than the lowest ME (3.05 ME). This establishes that broiler growth

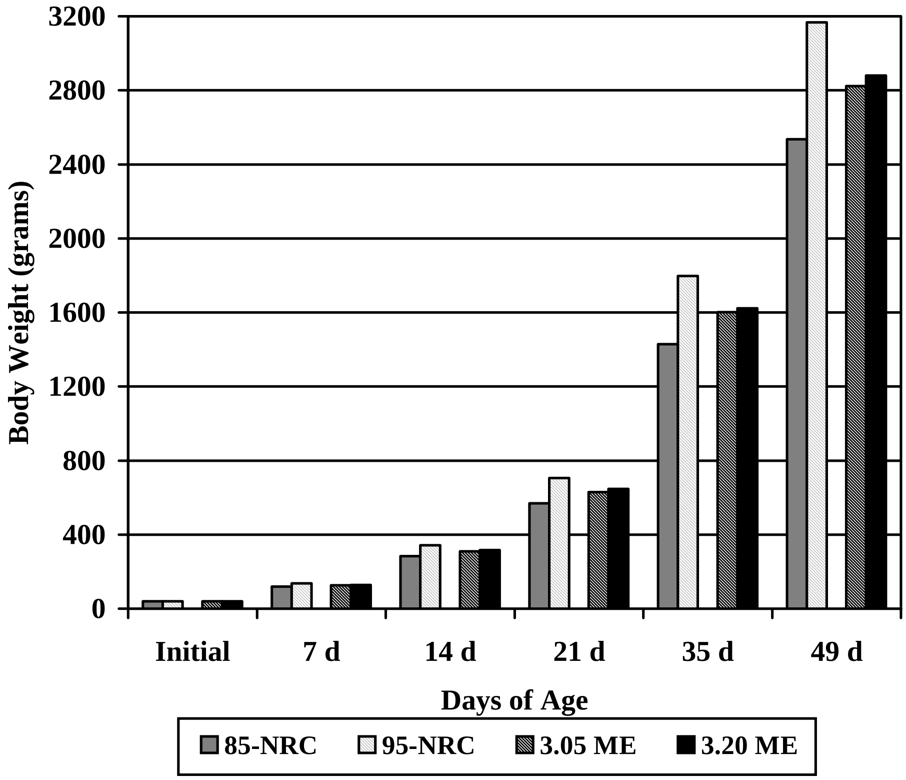

Figure 4.1. Body weight of male broiler chickens fed dietary treatments formulated at 85 % (85-NRC) and 95 % (95-NRC) of the NRC (1994) recommended minimums for the amino acids lysine, methionine, methionine + cystine at either 3.05 kcal/g and 3.20 kcal/g metabolizable energy (ME) for Experiment 4.

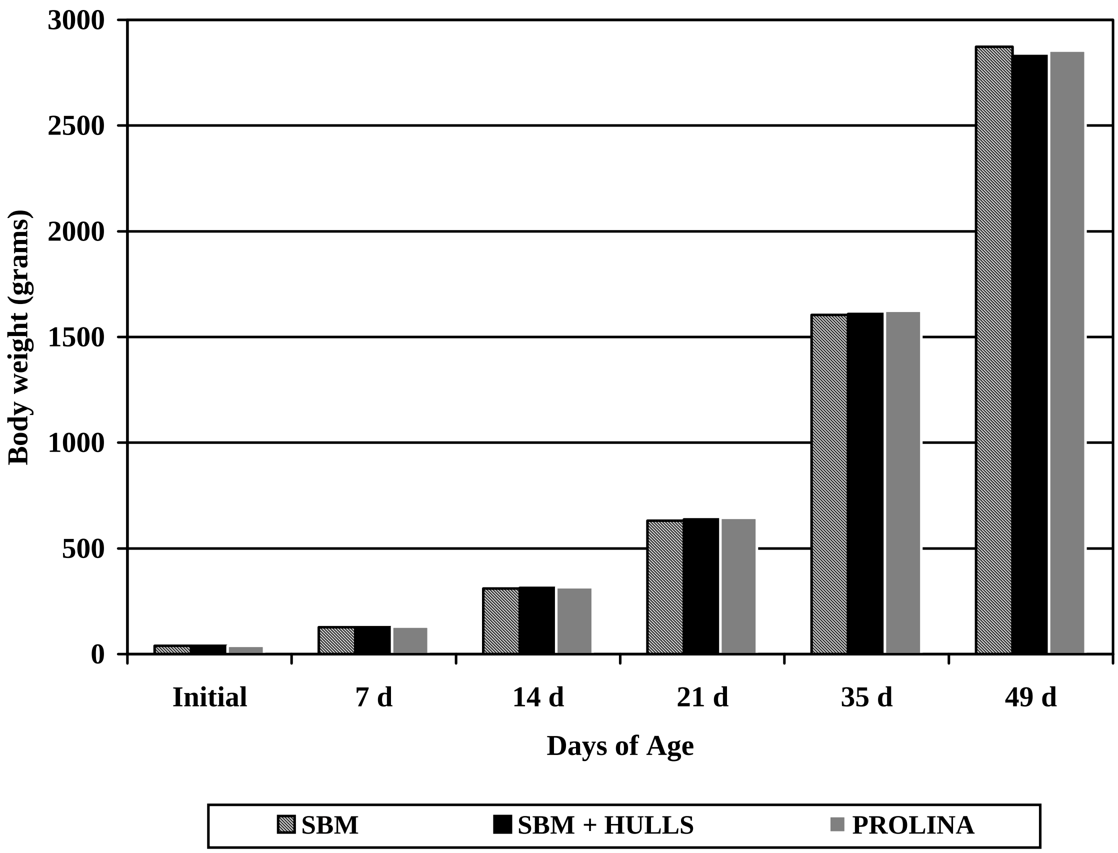

Figure 4.2. Body weight of male broiler chickens fed dietary treatments with either a commercially available soybean meal (SBM), commercially available soybean meal with added soybean hulls (SBM + HULLS) or Prolina soybean meal (PROLINA) substituted by weight as the soybean meal source for Experiment 4.

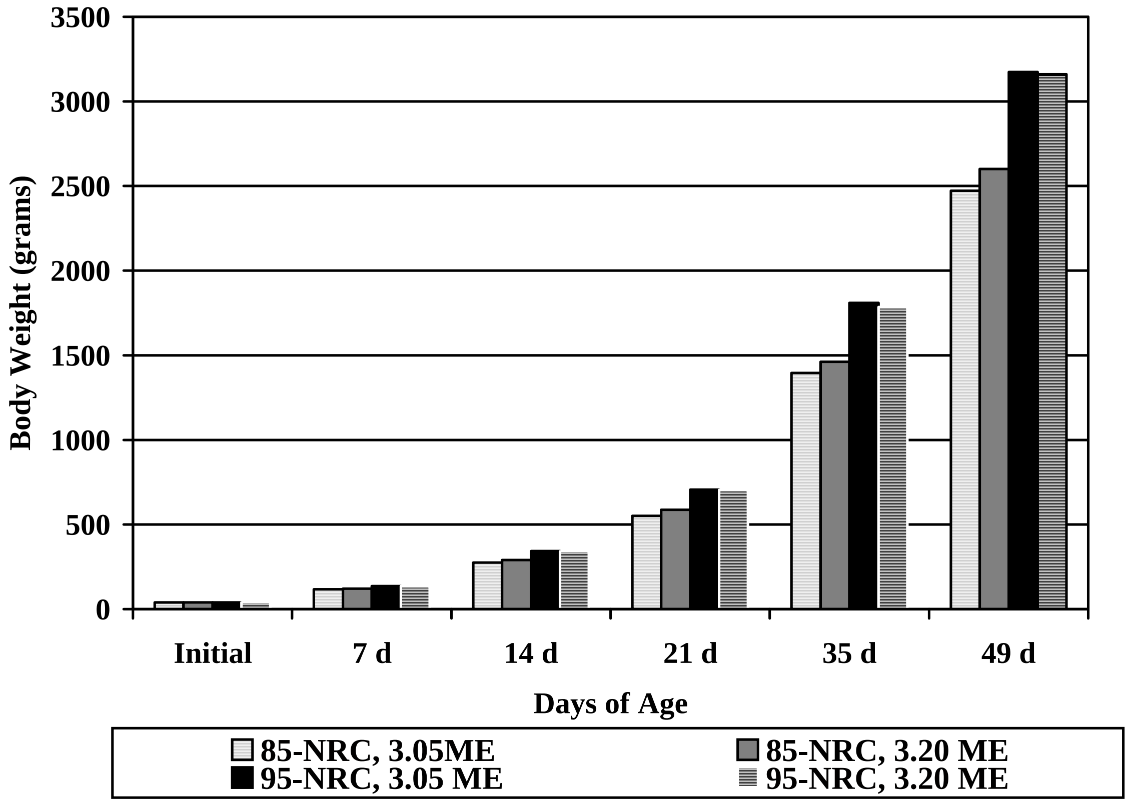

Figure 4.3. Body weight of male broiler chickens fed dietary treatments formulated 85 % (85-NRC) and 95 % (95-NRC) of the NRC (1994) recommended minimums for the amino acids lysine, methionine, methionine + cystine at either 3.05 kcal/g (3.05 ME) and 3.20 kcal/g (3.20 ME) metabolizable energy (ME) for Experiment 4.

could be limited by ME when CP is at deficient level, but this effect is not as detectable when CP levels are higher. Therefore, it would be expected that if a soybean meal source was contributing a higher CP or ME when substituted into the diet than other soybean meal sources, the BW effect would be evident among the diets formulated the lowest CP or ME.

With this in mind, Figure 4.4 outlines the interaction between dietary CP level (85-NRC and 95-NRC) and soybean meal source (SBM, SBM + HULLS, and PROLINA). There was no delineation of the interaction of CP and soybean meal source, as was anticipated. This suggests that perhaps Prolina soybean meal, expected to have a higher CP, was not providing an overall higher level of CP in a form that the broiler could utilize to optimize growth.

To investigate further, the interaction between dietary ME level (3.05 ME and 3.20 ME) and soybean meal source (SBM, SBM + HULLS, and PROLINA) is shown in Figure 4.5. At 49 d it was found that the 3.05 ME and PROLINA fed birds performed the same as the treatments formulated at 3.20 ME with any of three soybean meal sources. At the 3.05 ME level, the birds fed SBM + HULLS were significantly smaller than their PROLINA counterparts. This supports the concept described in Figure 4.3 and shows that when the ME is limiting, PROLINA is providing nutrients that could be used for energy by the broiler.

With the data provided by earlier experiments as well as that shown in Figures 4.1, 4.2, 4.3, and 4.4 it can be concluded that since no early BW response was found, even at deficient levels of CP, Prolina soybean meal was not providing additional CP in an amino acid profile that the bird could utilize directly for growth. However, the later

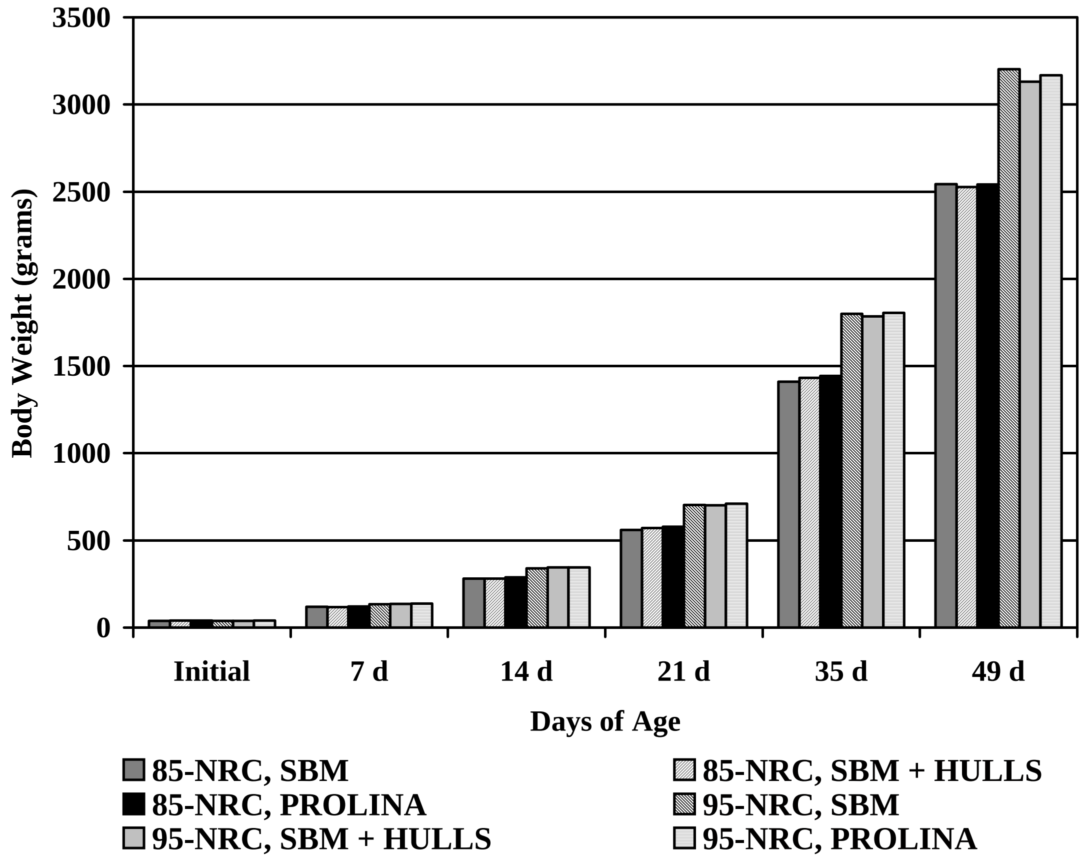

Figure 4.4. Body weight of male broiler chickens fed dietary treatments formulated at 85 % (85-NRC) and 95 % (95-NRC) of the NRC (1994) recommended minimums for the amino acids lysine, methionine, methionine + cystine using either commercially available soybean meal (SBM), commercially available soybean meal with added soybean hulls (SBM + HULLS) or Prolina soybean meal (PROLINA) substituted by weight as the soybean meal source for Experiment 4.

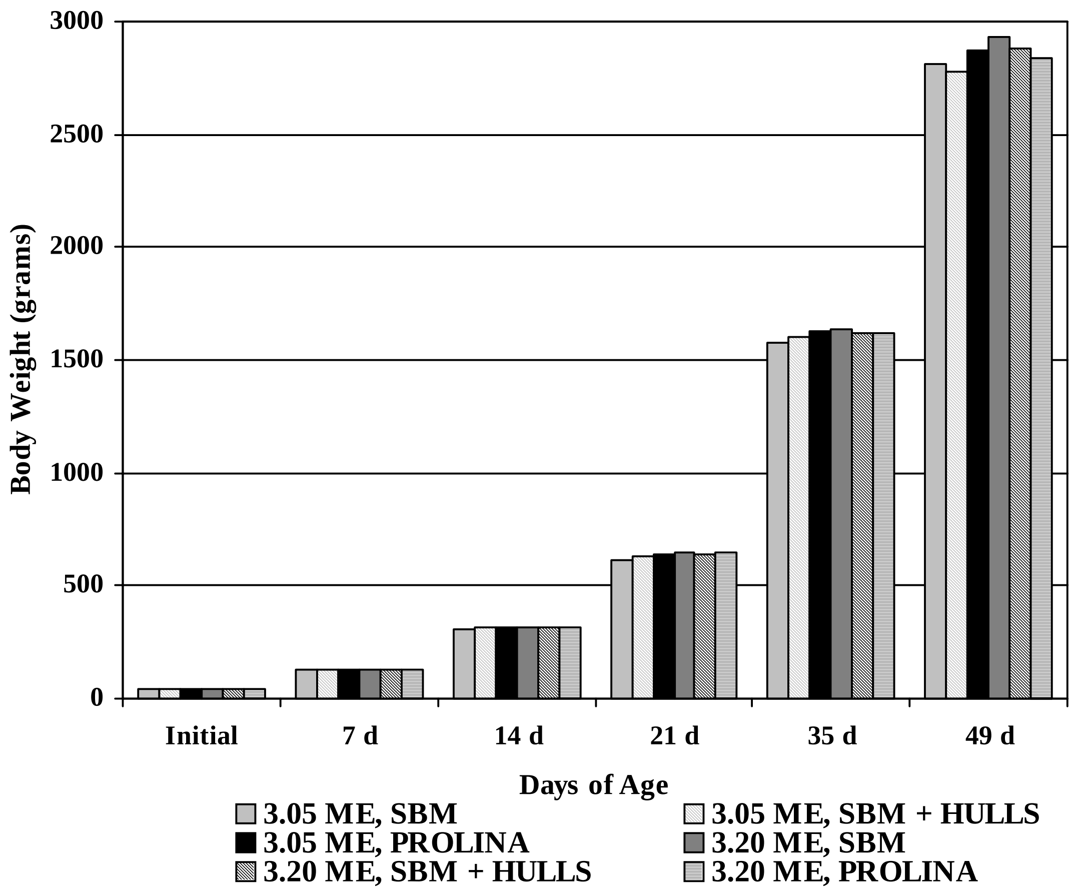

Figure 4.5. Body weight of male broiler chickens fed dietary treatments formulated at 3.05 kcal/g and 3.20 kcal/g metabolizable energy (ME) and with either a commercial variety soybean meal (SBM), a commercially variety soybean meal + soybean hulls (SBM + HULLS), or Prolina soybean meal (PROLINA) substituted by weight as the soybean meal source for Experiment 4.

growth response provided by Prolina soybean meal substitution, especially for the birds fed lower levels of ME, may indicate that Prolina soybean meal was providing the birds with a form of additional ME. It was thought that since the broiler could convert excess protein to energy, it was possible that the Prolina soybean meal was providing a higher level of CP in the form of non-essential amino acids. This would allow the bird to convert the excess amino acids to energy when dietary ME was deficient.

In general, the results of Experiment 4 repeated the results of the other experiments in Chapters 2 and 3. Broilers were found to respond to various level of CP and ME and it was shown that Prolina soybean meal could be substituted for the commercial variety soybean meal. Additional benefits of Prolina soybean meal substitution were found in diets that were limiting in CP and ME. Since the value of any soybean meal to the livestock industry lies in its nutrient content, specifically CP and ME, Prolina soybean meal could be of greater value than the commercially available version.

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CHAPTER 5

Effects of adjusting the amino acid profile of a broiler diet when using a soybean meal from a high protein cultivar

ABSTRACT. Higher protein "designer" soybeans are now being developed. An increase in soybean protein may be the result of a change in the ratio of glycinin (11S) and β-conglycinin (7S) subunits that form the storage proteins of a soybean. As a result of a different ratio, the amino acid profile can differ from that of a commercial variety of soybean. When using soybean meal from "designer" soybeans, it may be necessary to alter the typical amino acid supplementation in order to maximize broiler performance. Analysis of the soybean meal produced from one cultivar, Prolina, indicated a higher than normal level of CP and a change in the amino acid profile when compared to a commercial variety of soybean meal. Previous research has shown that diets containing a blend of Prolina and commercial variety soybean meals resulted in higher BW when compared to broilers fed diets with either of the soybean meals alone (Chapter 2, Experiment 2.2). The following experiment was designed to adjust the amino acid profile of Prolina soybean meal with threonine (third limiting amino acid) and to feed a blend of soybean meals. Cobb 500 strain broilers were fed starter, grower, and finisher diets that were formulated using the amino acid profile of a typical commercial variety of soybean meal. The Prolina soybean meal, the commercially available soybean meal, and a blend (1:1) of the two were individually substituted by weight as the soybean meal source for each dietary treatment. Each diet was then fed with or without supplemental synthetic L-threonine (THR) (to reach 105 % of NRC) in a 3 x 2 factorial.

At 21 d the birds fed the blend of the two soybean meals had the highest BW as compared to the commercial variety soybean meal with soybean hulls with the Prolina soybean meal intermediate. At 42 d the Prolina fed birds had the highest BW and AdjFCR as compared to the commercial variety with hulls with the blended soybean meals intermediate. Supplementation of THR did not affect BW or AdjFCR. However, THR supplemented birds had the best livability from 35 to 42 d when higher than normal environmental temperatures were experienced.

This study demonstrated that Prolina was a good substitute for the commercial variety of soybean meal, especially when measuring BW and AdjFCR of male broilers to market age. Also, THR supplementation in the diet reduced bird deaths due to heat stress.

Introduction

Poultry nutritionists must consider many factors when formulating a feed for a flock of broilers. One of the best tools available has been the computer-based least cost feed formulation programs, which allow nutritionists to easily create a diet that will theoretically maximize the performance of the birds at the lowest possible feed cost. Least cost formulation works by incorporating the least expensive combination of available ingredients that meet the specified requirements of the formula. Therefore, feed ingredients that can provide some cost advantage in this method of feed formulation can become quite important. For example, nutritionists assign value to high CP feedstuffs based on factors such as cost per unit CP, energy content, convenience of handling, and availability (Perry et al., 2003).

One of the more expensive components of a poultry feed tends to be CP. Although CP in the diet can come from several sources, meal produced from soybeans (*Glycine max.*)

has been the most popular protein feedstuff used in the United States due to its availability and consistent quality. Soybean meal, when combined with corn, provides poultry with an almost ideal amino acid balance that allows them to meet both their physiological and production needs (Baker et al., 1997; Klasing, 1998). Therefore, a particular type of soybean meal produced from a new cultivar must be evaluated on the amino acid profile that would be contributed to the complete diet.

Ideal amino acid balance appears to be a key concept when looking at the new soybean cultivars being developed under the United Soybean Board's Better Bean Initiative (USB, 2000). Soybean plants are being bred to posses enhanced genetic traits that have the potential to increase the value of the beans. Prolina soybean can be classified as an early example of this type of cultivar, as was discussed in Chapters 2, 3, and 4. It was shown by early analyses and prediction equations based upon the whole Prolina soybean that the soybean meal from Prolina would have higher CP content than the commercial variety soybean meal used in industry. However, the results of the early feeding trials using Prolina soybean meal (Experiments 2.2, 3.1, 3.2, and 4) did not indicate a large BW or AdjFCR improvement.

Therefore, it became important to more closely examine the amino acid availability and profile that existed in Prolina soybean meal. Interestingly, it had been determined that the proteins extracted from Prolina could be used to create unusually solid tofu food products (Kwanyuen et al., 1997). This action of strong protein-gel formation, different from that of a typical soybean, indicated an altered ratio of the subunits, glycinin (11S) and β-conglycinin (7S), used by the soybean to store protein (Saio et al., 1969; Yagasaki et al., 1997). It has been reported that as the glycinin and β-conglycinin ratio increases genotypically, methionine, cystine, and threonine content of the soybean have been thought to increase and lysine content decrease (Burton et al., 1982). However, the phenotypic expression of these genes has been reported to vary in each cultivar. This suggests that a possible change in the amino acid composition of Prolina soybeans could exist.

Even though the percentage amino acid analyses of the Prolina and commercially available soybeans appeared to be similar, as shown in Chapter 3 (Table 3.2), several small variations in the profile did exist. First, Prolina soybean meal was not compared to a fiber diluted counterpart. This caused a decreased percentage of amino acids for Prolina soybean meal due to the additional hulls in the meal. One of the most noticeable differences was the decreased percentage of threonine in the Prolina as compared to the sample of commercial variety soybean meal. Since threonine has been accepted to be the third-limiting amino acid (after methionine and lysine) in corn-soy based broiler diets and has been shown to be involved in many physiological functions such as body protein synthesis, feather synthesis, immune response, maintenance of tissues, and heat stress tolerance (Kidd et al., 2000), the apparently reduced THR level in the Prolina soybean meal was a concern.

Therefore, the following experiment was designed to evaluate the effects of Prolina soybean meal as a substitute for a commercially available variety, as well as to determine whether or not supplementing diets containing Prolina soybean meal with synthetic THR would improve the performance of the birds.

Materials and Methods

Soybean Meal Processing. Prolina soybeans were grown in Northeastern North Carolina by Eure Farms and processed at the Perdue Farms Soybean Processing Plant (Cofield, NC 27922) into soybean meal as described in Chapter 3. As was described in

Chapter 3, necessary adjustments were made by adding soybean hulls as a fiber source to the commercial variety of soybean meal to bring both meals to the same percentage fiber content.

Birds and Facility. Broiler chicks of the Cobb 500 strain were sexed and individually identified with neck tags at hatching. Nine hundred male broilers were randomly distributed among 36 pens (18 pens on each side of a central walkway) on the west end of a curtain-sided house with new wood shavings as litter. There were 25 birds placed in each pen, which measured 3.7 m long by 1.2 m wide. The heating components, airflow systems, and lighting schedules were as described in Chapter 3, Experiment 3.1.

Birds were provided feed and water for *ad libitum* consumption using two tube feeders and one bell waterer per pen. Supplemental feeders and waterers were placed on the floor of each pen to 7 d. Initially, 1135 grams per bird of crumbled starter feed was placed in each pen. At 21 d, grower feed was added on top of any remaining starter feed, and at 35 d, the finisher feed was added. Birds remained on finisher diets until the end of the experiment at 42 d.

Diets. Corn-soy basal starter, grower, and finisher diets were formulated to 100% NRC recommended values for lysine, methionine, and methionine + cystine with a calculated basal ME of 3.2 kcal ME/g. These formulations were initially carried out using a commercial variety soybean meal as the base. To create the dietary treatments either Prolina soybean meal (PROLINA), the commercial variety of soybean meal with hulls added (SBM+ HULLS), or a 50:50 blend of these two meals (BLEND) were substituted by weight as the soybean meal source in the diets. This was carried out in a manner similar to the method described in Chapter 3, Experiment 3.1. For Experiment 5, each diet either remained without supplement or was supplemented with synthetic threonine (L-Threonine, ADM, Decatur, IL 62521; Feed grade 98.5% availability) at the appropriate quantity to reach 105% of the NRC recommended threonine level in the diet. Thus, six dietary treatments were created. Clean white sand was substituted for threonine by weight in the diets without supplementation (Tables 5.1, 5.2, and 5.3). Samples of each diet were subjected to proximate (Woodson-Tenent Laboratories, Goldston, NC 27252) and amino acid analyses (Experiment Station Chemical Laboratory, University of Missouri, Colombia, MO 65211).

Data Collection. At placement, 7, 14, 21, 35 and 42 d BW and feed consumption were measured on a pen basis. High and low house temperatures were recorded twice daily by observation of four thermometers located at bird level in each corner pen in the house. Dead birds were weighed and recorded twice daily. The FCR and AdjFCR were calculated at weekly intervals. To provide an overall production efficiency comparison, the European Efficiency Factor[1] (EEF) was calculated for 21 d and 42 d data (Ross Broiler Manual, 1999).

Statistical Analysis. The experiment was a randomized complete block design consisting of two blocks and a 3 x 2 factorial (SBM source x THR) within each block. There were 3 replicate pens per block and a total of 36 experimental units. The two blocks consisted of 18 pens on each side of a central walkway. Statistical analysis was carried out using the General Linear Models procedure of SAS (SAS Institute, Inc., Cary, NC 1999-2001). No block effects were found and data from these analyses were omitted for brevity. Error was calculated from between replicate pen variation. Means were partitioned using the Duncan option. Statements of statistical significance were based on $P \leq 0.05$.

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[1] European Efficiency Factor (EEF) = Livability x Live weight in kg / (Age in Days x FCR)

Table 5.1. Analyses and compositions of starter diets used in Experiment 5.

Ingredients	Constants	PROLINA[1] THR	PROLINA[1] No THR	BLEND[3] THR	BLEND[3] No THR	SBM + HULLS THR	SBM + HULLS No THR
	(%)						
Prolina soybean meal[1]		33.15	33.15	16.58	16.58	…	…
Commercial soybean meal[2]		…	…	16.08	16.08	32.15	32.15
Soybean hulls		…	…	0.500	0.500	1.000	1.000
L-Threonine[4]		0.081	…	0.081	…	0.081	…
Sand (filler)		…	0.081	…	0.081	…	0.081
Corn	57.15						
Poultry fat	5.33						
Dicalcium phosphate	1.77						
Limestone (calcium carbonate)	1.12						
Salt (NaCl)	0.54						
Trace mineral premix[5]	0.20						
Vitamin premix[6]	0.05						
Choline chloride (60%)	0.20						
DL-Methionine	0.22						
Coccidiostat	0.07						
Selenium premix[7]	0.10						
Total		100.0	100.0	100.0	100.0	100.0	100.0
Calculated Analyses							
Metabolizable energy, kcal/kg	3200						
Crude protein, %	20.78						
Actual Analyses[8]							
Crude protein, %		23.64	22.87	21.72	24.01	21.48	20.26
Moisture, %		10.90	11.10	11.12	11.26	11.59	11.24
Fat, %		5.78	6.63	6.50	7.06	6.79	6.96
Fiber, %		3.10	2.80	3.20	2.90	3.10	3.10
Ash, %		5.16	5.42	5.42	2.60	5.28	5.52

[1] Prolina high protein soybean meal from the main batch added to constants (PROLINA).
[2] Commercial variety soybean meal with soybean hulls added to constants (SBM + HULLS).
[3] Equal mixture (1:1) of the Prolina and commercial soybean meal with hulls added to the constants (BLEND).
[4] Feed grade and guaranteed 98.5% availability L-Threonine (ADM, Decatur, IL 62521).
[5] Supplied per kg diet: manganese 120 mg, zinc 120 mg, iron 80 mg, copper 10 mg, iodine 2.5 mg, and cobalt 1.0 mg.
[6] Supplied per kg diet: retinol 6600 IU, cholecalciferol 2000 IU, vitamin E 33 IU, riboflavin 6.6 mg, niacin 55 mg, pantothenic acid 11 mg, vitamin K 2 mg, folic acid 1.1 mg, thiamine 2 mg, pyridoxine 4 mg, and biotin 126 ug.
[7] Selenium premix provided 0.10 mg selenium/kg of diet.
[8] Proximate analyses performed by Woodson-Tenent Laboratories, Goldston, NC 27252.

Table 5.2. Analyses and compositions of grower diets used in Experiment 5.

Ingredients	Constants	PROLINA[1] THR	PROLINA[1] No THR	BLEND[3] THR	BLEND[3] No THR	SBM + HULLS THR	SBM + HULLS No THR
		(%)					
Prolina soybean meal[1]		29.52	29.52	14.76	14.76	…	…
Commercial soybean meal[2]		…	…	14.36	14.36	28.72	28.72
Soybean hulls		…	…	0.400	0.400	0.800	0.800
L-Threonine[4]		0.068	…	0.068	…	0.068	…
Sand (filler)		…	0.068	…	0.068	…	0.068
Corn	61.51						
Poultry fat	4.72						
Dicalcium phosphate	1.79						
Limestone (calcium carbonate)	1.23						
Salt (NaCl)	0.49						
Trace mineral premix[5]	0.20						
Vitamin premix[6]	0.05						
Choline chloride (60%)	0.20						
DL-Methionine	0.06						
Coccidiostat	0.07						
Selenium premix[7]	0.10						
Total		100.0	100.0	100.0	100.0	100.0	100.0
Calculated Analyses							
Metabolizable energy, kcal/kg	3200						
Crude protein, %	19.35						
Actual Analyses[8]							
Crude protein, %		20.83	21.32	20.18	20.32	20.28	20.55
Moisture, %		11.03	10.74	10.73	10.95	10.01	10.74
Fat, %		6.41	6.61	7.88	7.03	7.51	6.83
Fiber, %		3.20	2.80	3.20	3.40	3.40	3.40
Ash, %		5.41	5.16	5.54	5.48	5.57	5.19

[1] Prolina high protein soybean meal from the main batch added to constants (PROLINA).
[2] Commercial variety soybean meal with soybean hulls added to constants (SBM + HULLS).
[3] Equal mixture (1:1) of the Prolina and commercial soybean meal with hulls added to the constants (BLEND).
[4] Feed grade and guaranteed 98.5% availability L-Threonine (ADM, Decatur, IL 62521).
[5] Supplied per kg diet: manganese 120 mg, zinc 120 mg, iron 80 mg, copper 10 mg, iodine 2.5 mg, and cobalt 1.0 mg.
[6] Supplied per kg diet: retinol 6600 IU, cholecalciferol 2000 IU, vitamin E 33 IU, riboflavin 6.6 mg, niacin 55 mg, pantothenic acid 11 mg, vitamin K 2 mg, folic acid 1.1 mg, thiamine 2 mg, pyridoxine 4 mg, and biotin 126 ug.
[7] Selenium premix provided 0.10 mg selenium/kg of diet.
[8] Proximate analyses performed by Woodson-Tenent Laboratories, Goldston, NC 27252.

Table 5.3. Analyses and compositions of finisher diets used in Experiment 5.

Ingredients	Constants	PROLINA[1] THR	PROLINA[1] No THR	BLEND[3] THR	BLEND[3] No THR	SBM + HULLS THR	SBM + HULLS No THR
				(%)			
Prolina soybean meal[1]		25.12	25.12	12.56	12.56	…	…
Commercial soybean meal[2]		…	…	12.18	12.18	24.37	24.37
Soybean hulls		…	…	0.38	0.38	0.75	0.75
L-Threonine[4]		0.069	…	0.069	…	0.069	…
Sand (filler)		…	0.069	…	0.069	…	0.069
Corn	66.77						
Poultry fat	3.99						
Dicalcium phosphate	1.82						
Limestone (calcium carbonate)	1.13						
Salt (NaCl)	0.46						
Trace mineral premix[5]	0.20						
Vitamin premix[6]	0.05						
Choline chloride (60%)	0.20						
DL-Methionine	0.02						
Coccidiostat	0.07						
Selenium premix[7]	0.10						
Total		100.0	100.0	100.0	100.0	100.0	100.0
Calculated Analyses							
Metabolizable energy, kcal/kg	3200						
Crude protein, %	17.63						
Actual Analyses[8]							
Crude protein, %		18.71	19.85	18.91	18.71	18.85	18.77
Moisture, %		11.07	11.09	11.44	11.13	12.15	11.58
Fat, %		6.04	6.51	6.00	6.23	6.05	5.70
Fiber, %		3.20	2.40	4.00	2.05	3.40	2.30
Ash, %		4.81	4.82	4.91	5.07	4.88	4.61

[1] Prolina high protein soybean meal from the main batch added to constants (PROLINA).
[2] Commercial variety soybean meal with soybean hulls added to constants (SBM + HULLS).
[3] Equal mixture (1:1) of the Prolina and commercial soybean meal with hulls added to the constants (BLEND).
[4] Feed grade and guaranteed 98.5% availability L-Threonine (ADM, Decatur, IL 62521).
[5] Supplied per kg diet: manganese 120 mg, zinc 120 mg, iron 80 mg, copper 10 mg, iodine 2.5 mg, and cobalt 1.0 mg.
[6] Supplied per kg diet: retinol 6600 IU, cholecalciferol 2000 IU, vitamin E 33 IU, riboflavin 6.6 mg, niacin 55 mg, pantothenic acid 11 mg, vitamin K 2 mg, folic acid 1.1 mg, thiamine 2 mg, pyridoxine 4 mg, and biotin 126 ug.
[7] Selenium premix provided 0.10 mg selenium/kg of diet.
[8] Proximate analyses performed by Woodson-Tenent Laboratories, Goldston, NC 27252.

Results

Diet Analyses. Proximate analyses were conducted on all diets and the results are shown in Tables 5.1, 5.2, and 5.3 for the starter, grower, and finisher diets, respectively. A direct comparison between the percentage CP analyses of the experimental diets and the calculated percentage CP values of the basal diet formulated using the nutrient values of a commercially available variety of soybean meal cannot be made, as this soybean meal was not one of the dietary treatments. It appeared that all dietary treatments had slightly higher percentage CP than the calculated value. However, the percentage CP of the SBM + HULLS treatment most closely resembled the calculated value. Diets receiving the THR supplementation had a higher percentage CP than those that were not supplemented, except the BLEND treatments. The BLEND with no THR supplementation had a higher percentage CP that the supplemented counterpart, however, the percentage fat value was slightly higher and percentage ash value was quite a bit lower (~2.5 %) than the values for all of the other treatment. Otherwise, the percentages of moisture, fat, fiber and ash had only small variations between samples.

The analyses of the grower diets showed similar percentage CP values among all dietary treatments and were within an acceptable range of the calculated value. The percentage moisture, crude fat, crude fiber, and ash were similar across treatments. However, for these samples, the addition of THR did not increase percentage CP.

The analyses of the finisher diets again showed similar percentage CP values for all dietary treatments and were slightly higher than the calculated value. The percentage moisture, crude fat, crude fiber, and ash were similar among treatments. The PROLINA with THR supplementation did not have a higher CP than the non-supplemented diet. It was interesting to note that all diets with supplemental THR had a higher percentage fiber.

Amino acid analyses were performed on each dietary treatment for the starter, grower, and finisher diets as shown in Tables 5.4, 5.5, and 5.6, respectively. Although variation among individual amino acids existed, there were only minor differences in amino acids exhibited among the dietary treatments for the starter, grower, and finisher diets.

Body Weight. The effect of diet on BW at 21 d and 42 d is shown in Table 5.7. At 21 d the birds fed the BLEND diets exhibited a significantly heavier BW than those fed the SBM+HULLS diet with PROLINA intermediate ($P \leq 0.01$). By 42 d the PROLINA diets produced the largest BW as compared to SBM+HULLS with the BLEND diet intermediate.

No significant differences were seen in the THR supplemented diets. No significant interactions were found and therefore were not reported for brevity.

Adjusted Feed Conversion Ratio. Table 5.7 shows AdjFCR for the broilers at 21 d and 42 d. At 21 d birds fed the diets containing the PROLINA and BLEND treatments had significantly better AdjFCR than the SBM+HULLS treatment. By 42 d PROLINA had significantly better AdjFCR than the other two treatments. No significant differences were found for the THR supplementation treatments. No significant interactions for AdjFCR were found throughout any of the dietary treatments and these were omitted for brevity.

Livability. Table 5.7 describes the cumulative livability 0 to 21 d and 0 to 42 d of age. No significant differences were found for cumulative livability from 0 to 21 d or 0 to 42 d among soybean meal or THR treatments. Table 5.8 describes weekly livability for the broilers fed the different dietary treatments. Although there were no statistical differences in livability among the soybean meal sources, the birds receiving the PROLINA had numerically better livability from 35-42 d. The birds receiving the THR

Table 5.4. Amino acid analyses of starter diets used in Experiment 5.

	PROLINA[2]		BLEND[3]		SBM + HULLS[4]	
Amino Acids[1]	THR[5]	No THR[5]	THR[5]	No THR[5]	THR[5]	No THR[5]
			(W/W %)			
Aspartic Acid	2.54	2.34	2.41	2.50	2.12	2.15
Threonine	0.90	0.74	0.83	0.86	0.74	0.72
Glutamic Acid	4.70	4.15	4.28	4.57	3.75	3.78
Proline	1.46	1.37	1.41	1.44	1.24	1.25
Glycine	0.97	0.90	0.92	0.96	0.83	0.84
Alanine	1.12	1.05	1.08	1.10	0.98	1.00
Cystine	0.45	0.43	0.44	0.46	0.41	0.45
Valine	1.21	1.14	1.21	1.16	1.03	1.04
Methionine	0.52	0.53	0.53	0.54	0.54	0.58
Isoleucine	1.06	0.97	1.04	1.00	0.89	0.88
Leucine	2.09	1.94	2.00	2.02	1.77	1.81
Lysine	1.32	1.22	1.26	1.31	1.10	1.12
Total	18.34	16.78	17.41	17.92	15.40	15.62

[1] Amino acid analysis performed by the laboratory of Dr. T.P. Mawhinney, University of Missouri, Colombia, MO 65211.
[2] Prolina soybean meal from the main batch added to constants to create dietary treatment (PROLINA).
[3] Equal mixture (1:1) of the Prolina and commercial soybean meal with hulls added to the constants to create dietary treatment (BLEND).
[4] Commercial variety soybean meal with soybean hulls added to the constants to create dietary treatment (SBM + HULLS).
[5] Feed grade and guaranteed 98.5% availability L-Threonine (ADM, Decatur, IL 62521).

Table 5.5. Amino acid analyses of grower diets used in Experiment 5.

Amino Acids[1]	PROLINA[2] THR[5]	PROLINA[2] No THR[5]	BLEND[3] THR[5]	BLEND[3] No THR[5]	SBM + HULLS[4] THR[5]	SBM + HULLS[4] No THR[5]
			(W/W %)			
Aspartic Acid	2.14	2.19	2.16	2.10	2.11	2.14
Threonine	0.73	0.68	0.75	0.74	0.73	0.74
Glutamic Acid	3.87	3.94	3.87	3.89	3.79	3.99
Proline	1.33	1.30	1.30	1.27	1.26	1.29
Glycine	0.84	0.84	0.84	0.81	0.83	0.83
Alanine	1.01	1.02	1.01	0.99	0.99	1.02
Cystine	0.42	0.42	0.43	0.37	0.45	0.42
Valine	1.06	1.06	1.05	1.00	1.04	1.03
Methionine	0.42	0.42	0.42	0.42	0.43	0.41
Isoleucine	0.89	0.91	0.90	0.86	0.87	0.86
Leucine	1.85	1.82	1.82	1.73	1.79	1.85
Lysine	1.10	1.11	1.11	1.05	1.08	1.09
Total	15.66	15.71	15.66	15.23	15.37	15.67

[1] Amino acid analysis performed by the laboratory of Dr. T.P. Mawhinney, University of Missouri, Colombia, MO 65211.

[2] Prolina soybean meal from the main batch added to constants to create dietary treatment (PROLINA).

[3] Equal mixture (1:1) of the Prolina and commercial soybean meal with hulls added to the constants to create dietary treatment (BLEND).

[4] Commercial variety soybean meal with soybean hulls added to constants to create dietary treatment (SBM + HULLS).

[5] Feed grade and guaranteed 98.5% availability L-Threonine (ADM, Decatur, IL 62521).

Table 5.6. Amino acid analyses of finisher diets used in Experiment 5.

Amino Acids[1]	PROLINA[2] THR[5]	PROLINA[2] No THR[5]	BLEND[3] THR[5]	BLEND[3] No THR[5]	SBM + HULLS[4] THR[5]	SBM + HULLS[4] No THR[5]
			(W/W %)			
Aspartic Acid	1.94	1.92	1.93	1.94	1.88	2.03
Threonine	0.69	0.65	0.72	0.62	0.67	0.70
Glutamic Acid	3.59	3.58	3.61	3.54	3.51	3.70
Proline	1.23	1.21	1.19	1.13	1.21	1.24
Glycine	0.77	0.76	0.76	0.81	0.75	0.79
Alanine	0.95	0.94	0.94	0.99	0.94	0.97
Cystine	0.38	0.40	0.39	0.37	0.38	0.39
Valine	0.96	0.96	0.94	0.99	0.95	0.99
Methionine	0.37	0.35	0.36	0.37	0.36	0.37
Isoleucine	0.78	0.78	0.77	.85	0.80	0.81
Leucine	1.73	1.69	1.71	1.68	1.67	1.75
Lysine	0.97	0.96	0.96	1.00	0.94	1.03
Total	14.36	14.20	14.28	14.29	14.06	14.77

[1] Amino acid analysis performed by the laboratory of Dr. T.P. Mawhinney, University of Missouri, Colombia, MO 65211.

[2] Prolina soybean meal from the main batch added to constants to create dietary treatment (PROLINA).

[3] Equal mixture (1:1) of the Prolina and commercial soybean meal with hulls added to the constants to create dietary treatment (BLEND).

[4] Commercial variety soybean meal with soybean hulls added to the constants to create dietary treatment (SBM + HULLS).

[5] Feed grade and guaranteed 98.5% availability L-Threonine (ADM, Decatur, IL 62521).

Table 5.7. Effect of soybean meal source and threonine supplementation on body weight, feed conversion ratio, and percentage livability at 21 and 42 days (d) of age in Experiment 5.

	21 d			42 d		
Main Effects[1]	BW	AdjFCR[2]	Livability[3]	BW	AdjFCR[2]	Livability[3]
	(g)	(g:g)	(%)	(g)	(g:g)	(%)
Soybean Meal [4] Source						
PROLINA	959[xy]	1.33[b]	98.3	2,837[a]	1.67[b]	96.3
BLEND	969[x]	1.34[b]	98.7	2,826[ab]	1.70[a]	95.7
SBM + HULLS	933[y]	1.37[a]	98.3	2,774[b]	1.70[a]	95.7
SE	11	0.01	0.1	19	0.01	0.2
Threonine Supplementation						
Yes	945	1.35	98.4	2,802	1.69	96.9
No	962	1.34	98.4	2,823	1.69	94.9
SE	9	0.01	0.0	11	0.0	1.0

[a,b] Means in a column within soybean meal source or threonine supplementation with no common superscripts differ significantly ($P \leq 0.05$).

[x,y] Means in a column within soybean meal source or threonine supplementation with no common superscripts approach a significant difference ($P \leq 0.10$).

[1] No significant interactions were found.

[2] Adjusted feed conversion ratio = feed consumed to age / (Live BW + BW of dead birds)

[3] Percentage birds remaining alive at the respective ages.

[4] The Prolina soybean meal from the main batch added to constant ingredients by weight to create the dietary treatment PROLINA. Commercial variety soybean meal with soybean hulls added to constants to create dietary treatment SBM +HULLS. A blend (1:1) of Prolina and commercial variety of soybean meal with soybean hulls added to constants to create the treatment BLEND.

Table 5.8. Effect of soybean meal source and threonine supplementation on percentage birds alive at 7, 14, 21, 35, and 42 days (d) of age in Experiment 5.

Main Effects[1]	Livability [2]				
Soybean Meal Source[3]	7 d	14 d	21 d	35 d	42 d
			(%)		
PROLINA	100.0	99.0	99.3	99.0	99.0
BLEND	99.0	100.0	99.7	99.7	97.3
SBM + HULLS	99.3	99.3	99.7	98.7	98.7
SE	0.3	0.3	0.1	0.3	0.5
Threonine Supplementation					
Yes	99.6	99.6	99.3	99.3	99.1^{a}
No	99.3	99.3	99.8	98.9	97.6^{b}
SE	0.1	0.1	0.2	0.2	0.8

[a,b] Means in a column within soybean meal source or threonine supplementation with no common superscript differ significantly ($P \leq 0.05$).

[1] No significant interactions were found.

[2] Percentage birds remaining alive at the respective ages.

[3] The Prolina soybean meal from the main batch added to constant ingredients by weight to create the dietary treatment PROLINA. Commercial variety soybean meal with soybean hulls added to constants to create dietary treatment SBM +HULLS. A blend (1:1) of Prolina and commercial variety of soybean meal with soybean hulls added to constants to create the treatment BLEND.

supplementation in their diet had significantly higher percentage livability as compared to those with no additional THR. No significant interactions were found.

Production Performance. The EEF was used to calculate the overall production performance of the birds grown on diets containing the different soybean meals with and without THR. The EEF was calculated using data (BW, FCR, livability, and days of age) for the time periods of 0 to 21d and 0 to 42 d (Table 5.9.)

For the main effect of soybean meal source from 0 to 21 d, the BLEND had a higher EEF ($P \leq 0.10$) as compared with the SBM + HULLS and the PROLINA intermediate. Numerically, PROLINA had the best overall production efficiency from 0 to 42 d as compared to the SBM + HULLS with the BLEND intermediate.

For the main effect of THR supplementation from 0 to 21 d, the birds with no additional THR had a numerically higher EEF than those with supplementation. However, by 42 d the birds with the additional THR had the best overall performance as indicated by the higher EEF number.

Discussion

The proximate and amino acid analyses of the dietary treatments demonstrated that, although there was no direct dietary treatment comparison, the treatments were all in general agreement with the calculated values for percentage CP (Table 5.1, 5.2, 5.3, 5.4, 5.5 and 5.6) although, for some samples, the analyses did not increase in percentage CP or specific amino acids as expected. Some concern arose regarding the analyses results of the dietary treatments with threonine added. These analyses did not always indicate an increase in percentage threonine. Perhaps these unexpected differences were due to poor sampling of the

Table 5.9. European Efficiency Factors (EEF) for birds fed various soybean meal sources and threonine supplementation at 21 and 42 d of age in Experiment 4.

Main Effects[1]		Days of Age	
		0-21	0-42
Soybean Meal Source[4]	Threonine Supplementation		
PROLINA		335[xy]	383
BLEND		340[x]	370
SBM + HULLS		317[y]	363
SE		7	6
	Yes	326	378
	No	337	366
SE		5	6

[x,y] Means in a column within soybean meal source or threonine supplementation with no common superscript approach significance ($P \leq 0.10$).

[1] No significant interactions were found.

[2] EEF = livability x live weight in kg / (age in days x FCR)

[3] The higher the value the better the technical performance.

[4] The experimental soybean meal (PROLINA). Added to constant ingredients by weight to create the dietary treatment PROLINA. Soybean hulls as typically used in industry, added to SBM as a fiber source by weight add to create (SBM +HULLS). A 1:1 ratio of the PROLINA and SBM+HULLS were used to create the BLEND treatment.

dietary treatments or other sources of variation. Unfortunately, only one sample of each diet was analyzed and therefore, information cannot be gathered to determine the source of the unexpected analytical results. Interestingly, PROLINA had the highest percentage CP as well as the highest total percentage for the individual amino acids analyzed.

Although no differences in percentage amino acids were apparent between dietary treatments, this analysis was conducted for only 12 of the amino acids. Differences may have existed in the non-essential amino acids that were beyond the scope of these particular analyses.

Regarding the performance of the birds, this study supported earlier conclusions and identified some interesting trends that had not been completely uncovered in the previous experiments. As was observed in Chapter 2, Experiment 2.2, the results of this experiment also reported that the blending of Prolina soybean meal with the commercial variety soybean meal improved performance of the young broilers. Apparently, the combination of the two nutrient profiles was more ideal for growth and feed efficiency than either one alone. Also, it was found that older birds (> 35 d of age) responded better to the PROLINA diets and that the addition of threonine improved livability in the older bird. However, threonine addition alone did not greatly improve bird BW or AdjFCR in this experiment.

To fully understand these results, it was important to note that this study was conducted in late spring and early summer. It was the case that as the birds aged, the weather became unusually hot. When the birds were at their later stages of growth, the temperatures reached high levels within the house. Figure 5.1 shows the daily bird deaths as they relate to the average daily high and low temperature within the house. The number of bird deaths

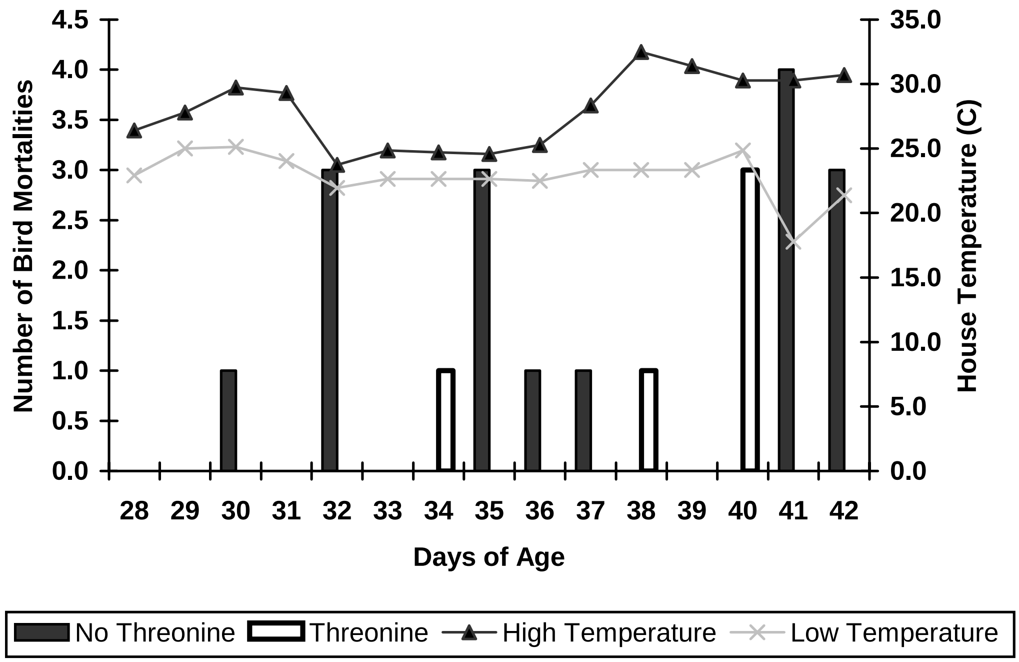

Figure 5.1. Number of daily bird mortalities for the dietary treatments with and without threonine supplementation in relation to the average daily high and low temperature of the house in Experiment 5.

increased as temperature within the house increased. The average daily high temperature in the house reached 32.5 C. It was at this point in the study, when the birds were 35 days and greater, that the THR diets supported the best livability. Upon review of the percentage amino acid digestibility (Chapter 3, Table 3.3) for Prolina soybean meal as compared to commercially available soybean meal, it was interesting to note that Prolina soybean meal had a high percentage digestibility for the amino acids threonine and arginine. Both of these amino acids have been linked to providing the bird with heat stress tolerance (Brake et al., 1998; Balnave et al., 1999; Chen et al., 2003; Kidd, 2000). From this information, it was reasonable to conclude that one of the reasons the PROLINA produced a heavier BW in this study was due to the survival of the largest birds of this treatment when the large birds in other treatments were succumbing to heat stress. This tolerance provided by PROLINA could have been the result of the higher digestibilities for the amino acids threonine and arginine. In other words, PROLINA appeared to be better balanced for late growth during heat stress in broilers.

Another possible advantage from the PROLINA diet as compared to the SBM + HULLS was that the Prolina soybean meal could provide extra ME in the form of additional non-essential amino acids that could be catabolized to glucogenic amino acids (when compared to an appropriate, fiber diluted commercial variety) as shown in Chapter 4. This could be similar for the THR diets, as the addition of the synthetic threonine could provide an excess of this amino acid that could be catabolized to the glucogenic amino acids, glycine and serine. With this in mind, it was known that when a broiler's body temperature begins to increase, as it would under heat stress conditions, its feed consumption may decrease. Perhaps as the temperature of the house increased, an artificial ME deficiency, due to decreased feed consumption, was created for these broilers allowing PROLINA fed and THR supplemented birds to have increased performance over the other treatments due to the conversion of certain amino acids that were in excess to energy.

It was important to recognize that the PROLINA fed birds also had the best overall EEF from 0 to 42 d. This was due in part to the improved livability, but also the other performance components, BW and FCR, which could increase the value of a broiler for a poultry producer. If value can be added to a broiler via inexpensive feedstuffs, there could potentially be great interest by commercial broiler nutritionists towards Prolina soybean meal.

Overall, Prolina soybean meal once again proved that it can be substituted for the commercial variety soybean meal in broiler diets without detrimental effects and will support normal broiler performance. The data from this experiment also suggested that Prolina soybean meal could have a different amino acid profile with regards to the non-essential amino acids, as compared to the commercial variety. Prolina could also have an advantage relative to its standard counterpart in areas that were prone to extreme heat or in diets that were deficient in ME.

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CHAPTER 6

Overall Discussion, Summary, and Conclusions

The six experiments (Experiment 2.1, 2.2, 3.1, 3.2, 4 and 5) presented in this thesis have outlined a methodology that evaluated Prolina soybean cultivar as a feedstuff in broiler chicken diets. It was through this process that a feeding value, relative to a commercial variety soybean meal typically used in poultry diets, was determined for Prolina soybean meal.

Prior to the start of these experiments, early analyses of whole Prolina soybeans reported a higher percentage CP relative to the commercial soybeans used in the industry. Therefore, the objective of these experiments was to screen the Prolina soybean meal for the effects of this higher CP with regards to the performance (BW, feed efficiency, and livability) of male broiler chickens. The first experiment conducted (Experiment 2.1) determined the response of male broiler chickens to various levels of dietary CP (lysine, methionine, and methionine + cystine based). Similar to results reported in other literature, Experiment 2.1 showed that modern commercial strains of male broilers can respond positively (increased BW, improved feed efficiency, and possibly improved livability) to levels of dietary CP in excess of the NRC (1994) recommended minimums. Therefore, it was anticipated that in Experiment 2.2, where a diet was formulated at the NRC (1994) minimums for CP and ME and Prolina soybean meal was substituted by weight for a commercial variety, the male broiler would have responded to the higher CP in Prolina soybean meal with the improved performance variables that were defined in Experiment 2.1. Unfortunately, no difference in performance was noted between the Prolina and the commercial variety soybean meals. In the next Experiment 3.1 the bird numbers were increased and soybean meals were adjusted with soybean hulls to create an equal fiber dilution with the expectation that the higher CP in Prolina would improve broiler performance. However, just as was seen in Experiment 2.2, no differences were noted between birds fed diets with Prolina soybean meal, a commercially available soybean meal, or a commercially available soybean meal adjusted with either soybean hulls or Solka Floc. To answer the question as to whether the results in Experiment 2.1 were repeatable, especially when broilers were moved from battery cages to floor pens, Experiment 3.2 was conducted to once again evaluate broiler performance when fed Prolina soybean meal substituted for a commercially available version as well as diets that were formulated at 100 % and 110 % NRC (1994). As expected, the broilers in Experiment 3.2 responded to the higher level of CP and repeated the improved performance that was seen in Experiment 2.2. However, as in Experiments 2.2 and 3.1, Experiment 3.2 failed to delineate any performance improvements for the broilers fed Prolina soybean meal. Since both Experiments 2.2 and 3.2 reported that male broilers would indeed respond to increased CP, it was thought that perhaps a limiting dietary ME was a factor masking the ability of the birds to respond to Prolina soybean meal. Experiment 4 followed and delineated the effects of dietary CP, ME, and the various soybean meal sources and their interactions on broiler performance. The affect of dietary CP, which was formulated at marginally deficient and severely deficient levels, on performance was repeated again in this experiment as was seen in the earlier experiments. Interestingly, Experiment 4 demonstrated that broiler performance could be altered by dietary ME level, but this effect was not seen until 14-21 d at which point birds fed higher levels of dietary ME had improved performance. And, as was seen in previous

Experiments 2.2, 3.1, and 3.2, no affect of soybean meal source on performance was found. However, the interaction of ME and soybean meal source illustrated that at the lower ME, Prolina soybean meal fed birds performed better than the diets with commercial soybean meal with soybean hulls and not different than the higher ME treatments. This can be explained using the interaction between CP and ME in Experiment 4, where birds fed lower ME were more sensitive to decreasing CP levels and they demonstrated poorer performance when fed the lowest levels CP and ME combinations. Therefore, it was thought that Prolina was in fact slightly higher in CP and that this could be measured by improved broiler performance when the dietary ME was limiting. Experiment 4 suggested that although no performance effects resulted from the feeding of Prolina in Experiments 2.2, 3.1, 3.2, and 4, Prolina did have a higher overall CP, consisting of amino acids that were not ideally balanced for improved growth or feed efficiency, but the additional amino acids could be utilized for energy when dietary ME and CP were moderate to severely deficient. Therefore, Experiment 5 was designed to improve the amino acid balance in Prolina to better facilitate improved growth and feed efficiency. The laboratory analyses of Prolina soybean meal identified threonine as a possible limiting factor in the amino acid profile (Chapter 3, Table 3.2). Therefore, diets were either supplemented with synthetic L-threonine or not and substituted with Prolina or commercial variety soybean meal. Experiment 5 determined that at 42 d the Prolina soybean meal fed broilers had the best overall performance. It was also found that the addition of threonine to the diets did not directly improve bird performance. With the previous experiments (2.2, 3.1, 3.2, and 4) having failed to detect an affect of Prolina soybean meal on performance, except when fed at marginal to deficient levels of CP and

ME combinations, it was decided to look closely at surrounding data. It was noted that a higher than normal number of bird deaths were attributed to heat stress in Experiment 5, and even though the overall mortality was relatively low, it was noted that the birds fed the diets containing Prolina or the diets supplemented with threonine had the best livability under these conditions. The amino acid digestibility analyses (Chapter 3, Table 3.3) had indicated that Prolina had a higher digestibility for the amino acids threonine and arginine, both which have been linked to improved livability under heat stress conditions (Brake et al., 1998; Kidd, 2000) and perhaps this provided the broiler with better heat stress tolerance. Also, similar to what was seen in Experiment 4, perhaps the broilers began to limit their intake of feed due to the heat stress and therefore created artificial deficiencies of dietary CP and ME. At this point, the additional CP provided by Prolina allowed the birds to survive and maintain BW, when birds on other treatments were decreasing in weight and succumbing to heat stress. Therefore, it was thought that the increased CP and amino acid profile of Prolina would be suited for heat stress tolerance.

Overall, the conclusion of these six experiments was that Prolina soybean meal was a suitable substitute for the commercially available variety that is typically used in broiler diets. Prolina soybean meal may potentially have increased value in areas of heat stress or in diets where CP and/or ME are limiting.

Future research should continue evaluation of Prolina soybean meal to fully discover what additional components of these soybeans may be affecting the broilers performance. For example, perhaps Prolina, which has recently been discovered to have a high level of phytate bound phosphorus, would provide better bird performance if phytase were included in the diet. Levels of other compounds or anti-nutritional factors (such as oligosaccharides) also need to be evaluated.

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