ABSTRACT

GODWIN, JENNIFER LEIGH. The Use of Degermed-Dehulled Corn to Reduce Phosphorus Excretion from Turkeys. (Under the direction of Dr. Jesse Grimes.)

Concerns about phosphorus (P) excretion into the environment from livestock and poultry in concentrated animal feeding operations (CAFOs) have made it necessary to examine alternative methods in which to reduce the amount of P that is excreted by the animal without impairing performance. To address this, alternate feed ingredients such as mechanically degermed-dehulled corn (DDC) and genetically modified, low-phytate, soybean meal (LP SBM), which both contain lower phytate phosphorus (PP) content, were used in a series of experiments in order to reduce phosphorus excretion from turkeys while maintaining overall performance. The first experimental objective was to determine the effect of using DDC compared to normal corn (NC) with three levels (85%, 100%, and 115% of recommended NRC levels) of calcium (Ca) and P at constant ratios in turkey starter diets. This use of DDC in place of NC resulted in equal overall performance for turkey poults raised from day of hatch to 21 days (d) of age. Phosphorus excretion was not affected by corn type; however, total fecal P was significantly reduced as dietary Ca and P decreased. The second experiment examined the effect of feeding LP SBM with three levels of Ca and P in turkey starter diets as described for experiment one compared to normal soybean meal (SBM) with 115% of NRC recommended Ca and P levels. The use of LP SBM in turkey starter

resulted in performance equal to that of poults fed SBM raised to 18 d. Phosphorus excretion was significantly lower when poults were fed LP SBM versus SBM and was significantly reduced as dietary Ca and P decreased. The third experimental objective was to examine the effect of feeding turkey poults a combination of DDC and LP SBM versus feeding a typical diet of NC and SBM with both grain combinations in turkey starter diets fed at three levels of Ca and P to 18 d. Feeding DDC and LP SBM together resulted in poult performance equal to using NC and SBM and, in addition, reduced fecal phosphorus. The fourth experiment examined the effect of feeding DDC in place of NC and two levels of Ca and P to turkeys raised to 18 wk. Turkeys fed DDC had similar body weight and feed conversions compared to turkeys fed NC. At 3 and 6 wk, fecal P was reduced when turkeys were fed lower Ca and P levels. The objective of the fifth experiment was to determine the effect of feeding DDC in place of NC with three levels of Ca and P to turkeys from 12 to 20 wk. Performance was similar between DDC and NC at 16 wk and 20 wk. At 20 wk, fecal P was reduced as dietary Ca and P levels decreased.

Overall, feeding DDC, especially in combination with LP SBM, resulted in similar turkey performance compared to the use of NC and SBM and also resulted in reduced P excretion. Feeding 100% of NRC recommended Ca and P appears to be adequate for rearing turkeys. In conclusion, this series of experiments provides evidence that feeding DDC and LP SBM do not affect growth parameters; however, it can provide the opportunity to reduce turkey P excretion. Feeding DDC, in combination with other nutritional practices such as also feeding LP SBM, could reduce turkey P excretion and, therefore, assisting in reducing P accumulation in environmentally sensitive water sheds located in turkey producing regions.

The Use of Degermed-Dehulled Corn to Reduce Phosphorus Excretion from Turkeys

by
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DEDICATION

To my mom, I carry you with me everyday.

BIOGRAPHY

Jennifer Leigh Godwin, daughter of Gene and Betty Jean Godwin, was born on January 24, 1975 in New Bern, North Carolina. She graduated from Northern Nash Senior High School, Rocky Mount, NC in 1993. She then entered North Carolina State University in Raleigh, NC in August 1993, majoring in Animal Science. In 1998 she received her Bachelor of Science degree in Animal Science with a minor in Poultry Science at North Carolina State University in Raleigh, North Carolina. In 2002, she received her Master of Science degree in Nutrition under the direction of Dr. Jesse Grimes. She decided to continue her studies at North Carolina State University in 2002 for the Doctor of Philosophy degree in Nutrition under the direction of Dr. Jesse Grimes.

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LITERATURE REVIEW

ENVIRONMENT

The US and global population continues to grow at a rapid pace, increasing the world-wide demand for quality animal protein products. This rise in demand has created the need for larger and more complex animal production facilities. The escalating number of confined animal feeding operations (CAFO's) in the past decade has in turn increased the generation of animal waste. This animal waste must then be disposed of within a limited area of land (Angel et al., 2002). While CAFO's are a sound economic and management approach; they have the potential to lead to a negative environmental impact (Barker, 1996; Mikkelsen, 1996). Currently, due to heightened environmental concerns, the social trend to regulate agricultural land management has become more prominent. In the US, legislative efforts are being made to regulate the manure disposal methods that were once commonplace, such as land application of waste (Coelho, 1996). Therefore, animal producers must examine alternative methods in which to promote economic production while minimizing and reducing nutrient waste.

Manure may be used for a variety of purposes such as a fuel source, feed supplement, or plant fertilizer (Barker and Zublena, 1995). Historically, animal manure was used as a plant fertilizer and was applied to the land in order to sustain soil fertility. However, the development of synthetic fertilizers that transformed agricultural productivity has inturn decreased the need for the nutrient value of animal manure as a fertilizer. Now, land application of manure is viewed as a method of waste disposal with the least amount of cost to the producer. It is this method of waste disposal combined with the nutrient content of manure and the improper land application that creates environmental concerns (Barker and Zublena, 1995; Mikkelsen, 1996; Williams et al., 1996). In animal manure, nitrogen (N) and phosphorus (P) tend to receive the greatest attention in efforts to reduce soil and water pollution. This section will focus on the inclusion of P in the diet and its subsequent excretion into the animal feces.

Manure properties are influenced by animal species, age, diet, productivity, management, and environment (Barker, 1996). Manures generally reflect the diet of the animals since they consist primarily of partially digested plant material and feed additives that are specially blended to maximize animal growth (Mikkelsen, 1996). Commercial poultry feeds are primarily seed based and most of the P present in these ingredients is in the form of phytin P (PP) (Nelson, 1976). The availability of PP for monogastric vertebrates is low and variable (Simons et al., 1990; Van der Klis and Versteegh, 1996). Therefore, supplemental quantities of inorganic P have been added to diets to meet the animals' P requirements. However, this practice may contribute to the increase of excreted P.

Typical land application of manure has been used to meet the nitrogen requirement of the growing crop (Zublena, 1994). However, when compared to needs of crops animal waste contains a disproportionate excess of P to N. However, in areas of intensive poultry operations the nutrient content of manure may often exceed the requirements for plant growth (Li et al., 2000). Over the past few decades, the presence of P in manure greater than crop removal rates have led to increases in soil P that now represent a risk to surface water quality (Sims et al., 2000).

The availability of manure P for plant nutrition depends on the mineralization of organic P compounds and the specific adsorption of the soil. Phosphorus is unlike nitrogen because it is generally bound tightly to soil particles and is only slightly soluble under most agricultural conditions (Mikkelsen, 1996). It is the erosion of sediment bound P soil particles from the land to the surface waters that present serious concerns for potential degradation of the environmental quality of those waters. Once sediment bound P reaches surface water, P solubility may increase and in turn stimulate biological activity resulting in eutrophication of the water.

The buildup of P in the environment and the resulting degradation of water resources are of increasing concern. This buildup is traceable to human activities including livestock production (Angel et al., 2002). Now, livestock industries must consider the full environmental impact of the increased production and distribution of animal manure in a relatively small location. Environmental concern and the expense of waste management are not independent; therefore, producers of poultry and other livestock must examine alternative methods in which to maintain economic production while minimizing and reducing nutrient waste. If the P content of animal feeds could be decreased without affecting animal growth and health, then the land application of lower P manure in areas with intensive animal rearing operations would result in a reduction of the buildup in soil P.

TURKEY REQUIREMENTS

Nutrition combines the knowledge of biochemistry and physiology into a working relationship between an organism and its food source which supplies the animal with the tools to function at optimum levels for processes such as growth, production, maintenance, and reproduction. Poultry diets are composed primarily of feedstuffs from plant origin such as corn and soybean meal. More than 60% of P in corn and soybean meal is in the form of phytate P (Reddy et al., 1982). Phytate is the storage form of P in plants and is responsible for the low bioavailability of P in such feedstuffs (Cromwell and Coffey, 1991). Producers need to make informed decisions based on animal health, production, and economics as to how they will meet the animals' nutritional needs, especially in the case of P, which is relatively expensive compared to calcium (Ca) (Coon and Leske, 2002). Failure to supply adequate amounts of P may lead to severe consequences in terms of reduced performance, excessive mortality, and reduction in carcass quality (Waldroup, 1999). In order to avoid production problems, nutritionists have utilized a margin of safety when formulating dietary P levels. In areas of concentrated animal production, excess undigested phytate P in the manure poses an environmental concern (Ibrahim et al., 1999; Maenz and Classen, 1998).

Phosphorus is widely distributed throughout the body which indicates its importance in many biological functions. While P is essential for proper formation and maintenance of bones, the majority of the P needs are related to skeletal development (Axe, 1998). Phosphorus is also needed for phosphorylation, high-energy phosphate bonds, and acid-base balance (Ewing, 1963). Phosphorus is also necessary for protein synthesis, is part of the vitamin-mineral relationship (Jurgens, 1984), and is required for efficient grain and feed utilization (Waldroup, 1995).

Formulating diets to meet the P requirement of poultry is a major economic and environmental challenge. There are a large number of interacting factors to consider when formulating a diet that can influence the bird's requirement for P such as Ca, vitamin D_3, age, dietary ingredients and feed processing. In 1994, the National Research Council listed the non-phytate P (nPP) dietary requirement level for turkey poults at 0.6% which agreed with earlier studies (Almquist, 1954; Bailey et al. 1986). The nPP dietary requirement decreases with the age of the turkey (Day and Dilworth, 1962). In 1950 and 1971, the nPP dietary requirement for laying turkey hens was listed at 0.75%. Since then, the recommended requirement has been lowered to 0.35% (NRC, 1984; 1994). The process of phytate P digestion and absorption is poorly characterized and large discrepancies in the retention of phytate P are reported in the literature. Digestion and retention of dietary phytate P varies with the form of phytate in the diet and the mineral and vitamin D status of the bird. Therefore, the P requirement of turkeys has not been fully defined.

Andrews et al., (1972) suggested that young poults could use a large portion of the organic P in the diet, depending upon the ingredient source. Peeler (1972) noted older birds hydrolyzed phytate P to a greater extent than young birds. In contrast, turkeys 8-20 weeks of age apparently did not utilize the phytin P in feedstuffs of plant origin (Sullivan, 1960). Several studies have been conducted in order to determine the turkey poult's requirement for P. Yan et al., (2003) suggested NRC (1994) recommendations were more than adequate for male Large White Turkeys grown to market weights. Roberson et al., (2004) noted there was no benefit to feeding nonphytate P at levels above NRC (1994) from 3 to 9 weeks of age; however, benefit was observed after 9 weeks of age for bone strength and mineralization. This wide range concerning the ability of poultry to utilize phytate P appears to be caused by the complex nature of phytate hydrolysis (Sebastian et al., 1998).

The dietary requirement for P can be estimated using a variety of methods with several different response criteria such as body weight gain, feed efficiency, P retention, and/or bone mineralization. The requirements for each of these responses are different in each case. For example, the P requirement to maximize bone is greater than that to maximize growth (Cromwell et al., 1970; Kornegay et al., 1981). Additionally, the physiological status of the bird can affect the P requirement for the different stages in life. Mudd and Stranks (1985), reported the relative amount of P deposited in bone decreases as the animal ages and as the skeletal structure becomes fully developed.

One of the most important functions of P is the mineralization of bone. Bone is highly specialized form of connective tissue that serves as a structural support for the body and as mobile storage for Ca and P. Bone development in the growing animal is important in determining Ca and P requirement for growth. Bone formation is highly dependent on the dietary concentration of Ca and P (Hart et al., 1992; Dunn, 1924). Bone formation is dependent not only upon the Ca and P concentrations, but the adequate intake of vitamin D3 is also essential (McGowan and Emslie, 1934).

The role of nutritional factors is probably most relevant to poultry bone strength. Calcium and P form 95% of the mineral matrices in bone (Rath et al., 2000), and about 85% of a bird's P is found in bone (Klasing, 1998). The source of P and its bioavailability affect bone strength (Hemme et al., 2005). Therefore, bone ash or breaking strength are frequently used as response criterion in studies to determine the P requirement (Klasing, 1998). There are several studies that provide the basis for specific recommendations of Ca and P by the NRC (1994) in poultry diets in order to achieve maximum growth and adequate bone development (Driver et al., 2005). Because bone is a dynamic tissue influenced by physiological and nutritional factors, it is important to understand bone formation and how these factors affect bone strength and quality.

The avian long bone is initiated by the buildup of cartilage in the epiphyseal growth plate found on each end of long bones (Bain and Watkins, 1993). Osteoblasts permeate the cartilage, first degrading it and then depositing collagen and hydroxyapatite within the template previously created by the cartilage (Klasing, 1998). The width of the bone is increased by the deposition of hydroxyapatite by osteoblasts onto the collagen matrix located on the periosteal (outer) surface of the bone (Howell and Dean, 1992). Osteoclasts are found on the endosteal (inner) surface of the bone and function to erode the internal calcified cartilage (Howell and Dean, 1992). It is this process of bone formation and resorption that permits the simultaneous increase in the diameter and length of the bone.

The avian long bones are made up of compact cortical bone which surrounds the trabecular bone (cancellous/spongy) and marrow space. Bone is first deposited as a random organization of collagen fibers called woven bone. This woven bone, in turn, is replaced by lamellar bone, a well organized arrangement of collagen, which assists with the bone's ability to resist torsion forces (Rath et al., 2000; Turek, 1984). The majority of bone is made of the bone matrix which is comprised of organic and inorganic parts. Bone is formed by the hardening of this matrix. Collagen is the major constituent of the organic matrix, contributing to the tensile strength of bone and providing oriented support to the mineral matrix (Riggs et al., 1993). The mineral matrix is predominantly Ca and P, in the form of hydroxyapatite, which constitutes approximately 60% to 70% of the bone weight and provides stiffness and compressional strength to the bone (Rath et al., 2000). Hydroxyapatite deposition imparts shear strength to the bone by binding to adjacent collagen fibers (Turek, 1984). Bone mineral density is the mass of material, organic and inorganic, per volume of bone, and is considered to reflect bone health (Rath et al., 2000).

The dietary requirements of P and its availability in feedstuffs of plant origin are key issues in poultry nutrition. Considerable variation is seen in research studies, in part due to various testing parameters such as age, stage of maturity, feed ingredients, and environment. This large number of interacting factors can influence the bird's requirement for P; therefore, further research is needed to determine the P requirements of turkeys without impairing performance.

PHYTIN PHOSPHORUS

Phytic acid, commonly referred to as phytate, is a myo-inositol with 6 structural positions capable of containing phosphate groups (Sebastian et al., 1998). Phytic acid serves several physiological functions and influences the nutritional properties of cereals, legumes and their derived foods by complexing with proteins and essential minerals. The terms phytic acid, phytate and phytin refer to free acid, salt, and Ca/Mg salt, respectively. Phytate is an organic complex regarded as the primary storage form for both phosphates and inositol in plants (Cosgrove, 1966). The concentration of phytate P in feedstuffs depends largely on the plant source from which it is derived (Sebastian et al., 1998; Cromwell et al., 1970), the stage of maturity, climate, method of processing, water availability, geographical location and the year during which they are grown (Reddy et al., 1982). Phytate P is found in different locations of the plant seed and is dependent upon the species of plant. For example, in corn, phytin is located in the germ portion of the seed (Harland and Oberleas, 1996). Phytate is a reactive anion that can form salts with dietary minerals (Oberleas, 1973; Erdman, 1979) and proteins (Cheryan, 1980; Cosgrove, 1980), thus reducing their solubility and digestibility when fed to animals.

Endogenous phytase enzymes exist in plants that are capable of hydrolyzing phytate P. However, these enzymes are present in variable quantities depending on the plant source, and significant amounts of these enzymes are unlikely to survive the highly acidic conditions (pH 1.0-2.5) of the proventriculus and gizzard (Hill, 1971), where the solubility of phytate is high (Von Sheuermann et al., 1998). Endogenous phytase in the plant is also heat liable and is readily inactivated at 70-80°C, the temperatures commonly used in feed processing (Jongbloed and Kemme, 1990).

Phytic acid is often perceived as an anti-nutritional factor due to its ability to chelate with minerals, protein, and starches in the digestive tract of animals to form insoluble complexes (Angel and Applegate, 2001). Phytic acid forms these insoluble complexes with polyvalent cations, thereby lowering the nutritional bioavailability of several trace minerals at both intermediate and high pH levels (Graf, 1983). The pH of the gastrointestinal tract (GIT) of birds increases as the digesta moves distally along the GIT. This increase in pH causes the phytate molecule to be ionized and more readily forms insoluble complexes with divalent metal cations such as Ca, Mg, Zn and Fe (Wise, 1983). These insoluble complexes precipitate out of solution thereby decreasing the availability of both phytate P and minerals associated with the insoluble complex (Angel at al., 2001). Furthermore, phytate is also able to bind with endogenous proteases such as trypsin and chymotrypsin in the GIT (Singh and Krikorian, 1982). These complexes may inhibit activity of those enzymes decreasing the digestibility of protein and amino acids (Namkung and Leeson, 1999).

It is this low bioavailability of P from the phytate molecule that creates the need to supplement the diet with inorganic P, subsequently increasing P excretion by the animal. Improving the availability of phytate P would enable a reduction of dietary P content resulting in a lower P excretion and a subsequently reduced environmental impact (Van der Klis et al., 1997).

DIETARY MODIFICATIONS

Most feeds of plant origin contain 50-80% of their total P as phytate (Common, 1940). While P is an essential mineral for growing turkeys, the ability of the bird to utilize phytate P is variable and controversial. Due to the high demand for adequate skeletal growth of the rapidly growing bird, it has been considered necessary to provide P in excess of NRC recommendations (Waldroup, 1999). This poses an environmental issue concerning the accumulation of P in soils from manure and the potential threat of eutrophication to the waterways. This issue challenges animal agriculture today. Therefore, it is necessary to develop cost effective methods to maintain poultry productivity while minimizing the P content in manure. Diet modification has been one of the fundamental methods for altering fecal P from poultry (Leytem et al., 2008; Maguire et al., 2004; Smith et al., 2004). Several methods are being studied to accomplish this goal such as: feeding closer to the bird's requirements, incorporation of feed additives (i.e. phytase, 25-hydroxycholecalciferol), use of genetically (i.e. low phytate soybeans) and mechanically (i.e. degermed-dehulled corn) modified feed ingredients.

In order to reduce fecal P, nutritionists must first determine the biological availability of the various sources of P in the diet as well as the turkey's requirements for P. The general assumption has been that poultry are unable to utilize phytate bound P and that the remaining plant P, together with supplemented P is completely available for utilization (Waldroup, 1999). However, it has been demonstrated that poultry are capable of using a portion of the phytate bound P and that the availability of supplemental P is less than 100% (Van der Klis and Versteegh, 1996). Since supplemental P generally provides approximately 60% of the nonphytate P needs of the bird, small differences in bioavailability may have significant impact on the fecal P content (Waldroup, 1999).

Adequate knowledge of the utilization of P in all feedstuffs, as well as the corresponding nutritional requirements at any production stage, is needed in order to formulate optimal diets for poultry. The National Requirements Council (1994) has published recommended levels of nPP at various stages of life of the bird. Nonphytate P is recommended at 0.6% of the diet for turkey poults (Almquist, 1954; Bailey et al., 1986) and this value has been shown to decrease with age (Day and Dilworth, 1962). Yan et al. (2003)

have shown that feeding P levels at NRC (1994) recommendations or lower could maintain productivity and reduce fecal P output.

Phytase is an enzyme known to release the orthophosphate group from the phytate molecule (Gibson and Ullah, 1990). Monogastric animals are limited in or lack the endogenous enzyme phytase which is necessary for the breakdown of phytate and release of P for absorption (Waldroup, 1999). It has been demonstrated that the addition of exogenous phytase enzyme to poultry diets is an effective way of both improving the availability of phytate bound P (Nelson et al. 1968; Simons et al., 1990; Kornegay et al., 1996) and decreasing fecal P (Yi et al., 1996). In weanling pigs, phytase supplementation resulted in a 50% increase in P retention and a 42% decrease in fecal P (Lei et al., 1993). Incorporation of phytase also has the potential to improve the utilization of other dietary nutrients, including amino acids and energy (Ravindran et al., 1998).

The form of vitamin D utilized in the diet may also be a factor in improving P retention while reducing fecal P (Ferket et al., 2002). Harrison and Harrison (1941) proposed that vitamin D deficiency has a direct effect on P metabolism and that vitamin D stimulates P transport mechanisms in the intestine (Harrison and Harrison, 1961; Biehl and Baker, 1997). The mode of action of vitamin D_3 on phytate P utilization is unclear. However, it is known that vitamin D_3 increases Ca absorption by stimulating synthesis of Ca binding proteins in enterocytes (Cromwell, 1996). Calcium is known to form insoluble complexes with phytate which would render phytate unavailable for hydrolysis (Maenz et al., 1999).

The increase in Ca absorption decreases the concentration of Ca in the intestinal lumen reducing the formation of Ca-phytate complexes which could increase the hydrolysis of phytate P by endogenous phytases present at the mucosal surface (Biehl and Baker 1997).

Dietary strategies have also included new plant genotypes that contain substantially less phytate P aiding monogastric animals that cannot fully digest phytate P (Raboy et al., 2000). Low phytate varieties have been developed for several ingredients such as corn, barley and soybeans. These new plant genotypes contain the same level of total P as normal varieties; however, the phytate P is only 35% of the total P versus 75 to 80% of the total P in normal varieties (Stillborn, 1997; Stillborn, 1998). It has been shown that feeding low phytate grains improves P utilization (Li et al., 2001) and reduces P excretion in poultry (Jang et al., 2003: Penn et al., 2004).

Another approach to reducing dietary P levels and minimizing P in the excreta is to mechanically develop feedstuffs with modified levels of phytate bound P. In cereals, phytate is associated with specific components within the grain and can be preferentially separated with those components. The whole corn kernel consists of an embryo or germ, an endosperm enclosed by a nucellar epidermis and a seed coat surrounded by a fruit coat or pericarp (Hoseney, 1994). The hull constitutes approximately 5-6% of the kernel; the germ is 10-14% of the kernel with the remainder being the endosperm (Hoseney, 1994). The biosynthesis, accumulation, and dephosphorylation of phytate in seeds and grains confined to electron-dense regions called globoids or aleurone particles. In seeds and grains the globoids are associated with germ, aleurone layer, scutellum, and cotyledons or endosperm, and vary with plant species (Scott and Loewus, 1986). In corn, approximately 88% of phytate is concentrated in the germ portion of the kernel (O'Dell et al., 1972).

Degermed-dehulled corn (DDC) is a derivative of the corn dry milling process. The dry milling process separates the whole corn into several fractions: corn germ, hull, and the endosperm. The germ and hull fractions are typically sold as animal feed ingredients. The endosperm is further separated to produce endosperm particles of different sizes. Degermed-dehulled corn is derived from the remaining, smaller fraction of the endosperm (Alexander, 1987). Advantages of DDC versus whole corn as a feed ingredient include lower fiber content, higher energy content and a lower phytate P content. Therefore, removal of these phytate P rich fractions should have a significant impact on the nutrient composition of corn and potentially enhance its nutritional value.

The objective of this research is to evaluate feeding DDC, as an alternative to normal corn, on turkey performance and fecal P content.

REFERENCES

Alexander, R. J., 1987. Corn dry milling: processes, products, and applications, In: Corn Chemistry and Technology. S. A. Watson and P. E. Ramstad (ed) pp 351-376. Amer. Assoc. Cereal Chem., Inc., St. Paul, MN.

Almquist, H. J., 1954. The phosphorus requirement of young chicks and poults-A review. Poult. Sci. 33:936.

Angel, R., and T. Applegate, 2001. Phytase use – What do we know? in: Proc. Of the 62nd Minnesota Nutrition Conf. and Minnesota Corn Growers Assn. Tech. Symp., Bloomington, MN. pp250-263.

Angel, R., N. M. Tamim, T. J. Applegate, A. S. Dhandu, and L. E. Ellestad, 2002. Phytic acid chemistry: influence on phytin-phosphorus availability and phytase efficacy. J. Appl. Poult. Res. 11:471-480.

Axe, D. E., 1998. Phosphorus value in ingredient sources examined. Feedstuffs 70(22):17-19.

Bailey, C. A., S. Linton, R. Brister, and C. R. Creger, 1986. Effects of graded levels of dietary phosphorus on bone mineralization in the very young poult. Poult. Sci. 65:1018-1020.

Bain, S. D., and B. A. Watkins, 1993. Local modulation of skeletal growth and bone modeling in poultry. Journal of Nutrition 123:317-322.

Barker, J. C., and J. P. Zublena, 1995. Livestock manure nutrient assessment in North Carolina. in: Proceedings of the Seventh International Symposium on Agricultural and Food Processing Wastes. American Society of Agricultural Engineers, Chicago, IL. pp. 98-106.

Barker, J. C., 1996. Swine and poultry manure production and characteristics. in: Phytase in Animal Nutrition and Waste Management. M. B. Coelho and E. T. Kornegay, eds. A BASF Reference Manual, pp. 1-16.

Belanger, G., 2000. Phytase, more than an environmental tool. Agriculture and Food, Government of Saskatchewan, Canada. http://www.agr.gov.sk.ca.html.

Biehl, R. R. and D. H. Baker, 1997. Utilization of phytate and non phytate phosphorus in chicks affected by source and level of vitamin D3. J. Animal Science 75:2986-2993.

Cheryan, M., 1980. Phytic acid interactions in food systems. CRC Critical Reviews in Food Science Nutrition Chem., Rubber Co. 13:297-302.

Common, R. H., 1940. The phytic acid content of some poultry feed stuffs. Analyst 65:79-83.

Cosgrove, D. J., 1966. The chemistry and biochemistry of inositol polyphosphates. Review of Pure Applied Chemistry 16:209-215.

Cromwell, G. L., V. W. Hayes, C. H. Chaney, and J. R. Overfield, 1970. Effects of dietary phosphorus and calcium level on performance, bone mineralization and carcass characteristics of swine. J. Anim. Sci. 30:519-525.

Cromwell, G. L., and R. D. Coffey, 1991. Phosphorus - A key essential nutrient, yet a possible major pollutant – Its central role in animal nutrition. Pages 133-145 in: Biotechnology in the Feed Industry. T. P. Lyons ed. Alltech Publications, Nicholasville, KY.

Day, E. J., and B. C. Dilworth, 1962. Dietary phosphorus levels and calcium:phosphorus ratios needed by growing turkeys. Poult. Sci. 41:1324.

Driver, J. P., G. M. Pesti, R. I. Bakalli, and H. M. Edwards, Jr., 2005. Calcium requirements of the modern broiler chicken as influenced by dietary protein and age. Poult. Sci. 84:1629-1639.

Dunn, L. C., 1924. Effect of cod-liver oil in various amounts and forms on the growth of young chickens. J. Biol. Chem. 61:129.

Erdman, J. W., 1979. Oilseed phytates: nutritional implications. J. Am. Oil. Chem. Soc. 56(8):736-741.

Ewing, W. R., 1963. Poultry Nutrition. Fifth Edition (Revised). The Ray Ewing Company, Pasadena, California.

Ferket, P. R., T. A. van Heughten, T. G. van Kempen, and R. Angel, 2002. Nutritional strategies to reduce environmental emissions from nonruminants. J. Anim. Sci. 80 (E. Suppl. 2):E168-E182.

Gibson, D. M. and A. B. J. Ullah, 1990. Phytase and their actions on phytic acid. Pages 77-92 in: Inositol Metabolism in Plants. D. J. Moore, W. F. Boss, and F. A. Loewus, ed. Wiley-Liss, Inc., New York, NY.

Graf, E., 1983. Applications of phytic acid. JAOCS, vol. 60, no. 11, 1861-1867.

Harrison, H. E. and H. C. Harrison, 1941. The renal excretion of inorganic phosphate in relation to the action of vitamin D and parathyroid hormone. J. Clin. Invest. 20:47-55.

Harrison, H. E. and H. C. Harrison, 1961. Intestinal transport of phosphate: action of vitamin D, calcium and potassium. Am. J. Physiol. 201:1007-1012.

Hart, E. B., J. G. Halpin, and H. Steenbeck, 1992. Nutritional requirements of baby chicks. II. Further study of leg weakness in chickens. J. Biol. Chem. 52:379.

Hemme, A., M. Spark, P. Wolf, H. Paschertz, and J. Kamphues, 2005. Effects of different phosphorus sources in the diet on bone composition and stability (breaking strength) in broilers. J. Anim. Physiol. Anim. Nutr. (Berl) 89:129-133.

Hill, K. J., 1971. The physiology of digestion. In: Physiology and Biochemistry of the Domestic Fowl. D. J. Bell, B. M. Freeman, ed., Vol. 1. Academic Press, London, UK. p 25.

Hoseney, R. C., 1994. Structure of cereals, In: Principles of Cereal Science and Technology. pp 1-28. Amer. Assoc. Cereal Chem. Inc. St. Paul. MN.

Ibrahim, S., J. P. Jacob, and R. Blair, 1999. Phytase supplementation to reduce phosphorus excretion of broilers. J. Appl. Poultry Res. 8:414-425.

Jang, D. A., J. G. Fadel, K. C. Klasing, A. J. Mireles, Jr., R. A. Ernst, K. A. Young, A. Cook, and V. Raboy, 2003. Evaluation of low-phytate corn and barley on broiler chick performance. Poult. Sci. 82:1914-1924.

Jongbloed, A. W., and P. A. Kemme, 1990. Effect of pelleting mixed feeds on phytase activity and the apparent absorbability of phosphorus and calcium in pigs. Animal Feed Science and Technology 28:233-242.

Jurgens, M. H., 1984. Animal Feeding and Nutrition. 5th ed. Kendall/Hunt Publishing, Co., Dubuque, IA.

Klasing, K. C., 1998. Minerals. in: Comparative Avian Nutrition. CAB International, New York, NY. pp 234-276.

Kornegay, E. T., H. R. Thomas, and J. L. Baker, 1981. Phosphorus in swine. IV. Influence of dietary calcium and phosphorus and protein levels on feedlot performance, serum mineral, bone development and soundness scores in boars. J. Anim. Sci. 52:1070-1090.

Kornegay, E. T., Z. Yi, V. Ravindran, and D. M. Denbow, 1996. Improving phytate phosphorus availability in corn and soybean meal for broilers using microbial phytase and calculation of phosphorus equivalency values for phytase. Poult. Sci. 75:240-249.

Kornegay, E. T., 1998. Nutrient management can reduce nutrient excretion. Feedstuffs. 70(21):14-15.

Lei, X. G., P. K. Ku, E. R. Miller, and, M. T. Yokoyama, 1993. Supplementing corn-soybean meal diets with microbial phytase linearly improves phytate utilization in weanling pigs. J. Anim. Sci. 72:139-143.

Leytem, A. B., P. W. Plumstead, R. O. Maguire, P. Kwanyuen, J. W. Burton, and J. Brake, 2008. Interaction of calcium and phytate in broiler diets. 2. Effects of total and soluble phosphorus excretion. Poult. Sci. 87:459-467.

Li, Y. C., D. R. Ledoux, T. L. Veum, V. Raboy, and D. S. Ertl, 2000. Effects of low phytic acid corn on phosphorus utilization, performance, and bone mineralization in broiler chicks. Poult. Sci. 29:1444-1450.

Li, Y. C., D. R. Ledoux, T. L. Veum, V. Raboy, K. Zyla, and A. Wikiera, 2001. Low phytic acid barley improves performance, bone mineralization, and phosphorus retention in turkey poults. J. Appl. Poult. Res. 10:178-185.

Maenz, D. D., and H. L. Classen, 1998. Phytase activity in the small intestinal brush border membrane of the chicken. Poult. Sci. 77:557-563.

Maenz, D. D., C. M. Engele-Schaan, R. W. Newkirk, and H. L. Classen, 1999. The effect of minerals and mineral chelators on the formation of phytase-resistant and phytase-susceptible forms of phytic acid in solution and in a slurry of canola meal. Animal Feed Science and Technology 81:177-192.

Maguire, R. O., J. T. Sims, W. W. Saylor, B. L. Turner, R. Angel, and T. J. Applegate, 2004. Influence of phytase addition to poultry diets on phosphorus forms and solubility in litters and amended soils. J. Environ. Qual. 33:2306-2316.

McGowan, J. P., and A. R. G. Emslie, 1934. Rickets in chickens, with special reference to its nature and pathogenesis. Biochem. J. 28:1503.

Mikkelsen, R. L., 1996. Best management practices for plant nutrients. in: Phytase in Animal Nutrition and Waste Management. M. B. Coelho and E. T. Kornegay, eds. A BASF Reference Manual, pp. 29-40.

Mudd, A. J., and M. H. Stranks, 1985. Mineral and trace element requirements of pig. In: Recent Developments in Pig Nutrition. P. J. A. Cole and W. Haresign (ed.), Butterworths, London, pp. 124-138.

Namkung, H., and S. Leeson, 1999. Effect of phytase enzyme on dietary nitrogen-corrected apparent metabolizable energy and the ileal digestibility of nitrogen and amino acids in broiler chicks. Poult. Sci. 78:1317-1319.

National Research Council, 1950. Nutrient requirements of domestic animals. No. 1. Nutrient requirements for poultry. National Academy Press, Washington, DC.

National Research Council, 1971. Nutrient requirements of domestic animals. No. 1. Nutrient requirements for poultry. National Academy Press, Washington, DC.

National Research Council, 1988. Nutrient requirements for poultry. 8th rev. ed. National Academy Press, Washington, DC.

National Research Council, 1994. Nutrient requirements for poultry. 9th rev. ed. National Academy Press, Washington, DC.

Nelson. T. S., 1967. The utilization of phytate phosphorus by poultry – a review. Poult. Sci. 46:862.

Nelson, T. S., L. W. Ferrara, and N. L. Storer, 1968. Phytate phosphorus content of feed ingredients derived from plants. Poult. Sci. 47:1372.

Nelson, T. S., 1976. The hydrolysis of phytate phosphorus by poultry: a review. Poult. Sci. 46:862-871.

O'Dell, B. L., A. deBoland, and R. Koirtyohann, 1972. Distribution of phytate and nutritionally important elements among the morphological components of cereal grains. J. Agric. Food Chem., 20, 718.

Oberleas, D., 1973. Phytates: in: Toxicanl Occurring Naturally in Foods, 2nd Edition. National Academy of Sciences, Washington, DC pp 363-371.

Peeler, H. T., 1972. Biological availability of nutrients in feeds: Availability of major mineral ions. J. of Animal Sci. 35:695.

Penn, C. J., G. L. Mullins, L. W. Zelazny, J. G. Warren, and J. M. McGrath, 2004. Surface runoff losses of phosphorus from Virginia soils amended with turkey manure using phytase and high available phosphorus corn diets. J. Environ. Qual. 33:1431-1439.

Raboy, V., P. F. Gerbasi, K. A. Young, S. D. Stoneberg, S. G. Pickett, A. T. Bauman, P. P. N. Murthy, W. F. Sheridan, and D. S. Ertl, 2000. Origin and seed phenotype of maize low phytic acid 1-1 and low phytic acid 2-1. Plant Physiol. 124:355-368.

Rath, N. C., G. R. Huff, W. E. Huff, and J. M. Balog, 2000. Factors regulating bone maturity and strength in poultry. Poult. Sci. 79:1024-1032.

Ravindran, V., S. Cabahug, W. L. Bryden, and P. H. Selle, 1998. Influence of microbial phytase on energy and protein utilization in broilers. Proc. Maryland Nutrition Conference for Feed Manufacturers, University of Maryland, University Park, pp. 156-165.

Reddy, N. R., M. D. Pierson, S. K. Sathe, and D. K. Salunkhe, 1989. Phytates in Cereals and Legumes.

Riggs, C. M., L. C. Vaughan, G. P. Evans, L. E. Lanyon, and A. Boyde, 1993. Mechanical implication of collagen fibre orientation in cortical bone of equine radius. Anat. Embryol. 187:239-248.

Roberson, K. D. M. W. Klunzinger, and R. A. Charbeneau 2004. Benefit of feeding dietary calcium and nonphytate phosphorus levels above National Research Council recommendations to tom turkeys in the growing-finishing phases. Poultry Sci. 83:689-695.

Scott, J. J. and F. A. Loewus. Phytate metabolism in plants, in: Phytic Acid: Chemistry and Applications, Graf, E., Ed., Pilatus Press, Minneapolis, 1986. 43.

Sebastian, S., S. P. Touchburn, and E. R. Chavez, 1998. Implications of phytic acid and supplemental microbial phytase in poultry nutrition: a review. World’s Poultry Sci. 54:27-47.

Sims, J. T., A. C. Edwards, O. F. Schoumans, and R. R. Simard, 2000. Integrating soil phosphorus testing into environmentally based agricultural practices. J. Environ. Qual. 29:60-71.

Simmons, P. C. M., H. A. J. Versteegh, A. W. Jongbloed, P. Slump, K. D. Bos, M. G. E. Wol Beudeker, and G. J. Verchoor, 1990. Improve phosphorus availability by microbial phytase and pigs. Br. J. Nutr. 64:525-540.

Singh, M., and A. D. Krikorian, 1982. Inhibition of trypsin activity in vitro by phytate. J. Agric. Food Chem. 30:799-800.

Smith, D. R., P. A. Moore, D. M. Miles, B. E. Haggard, and T. C. Daniel, 2004. Decreasing phosphorus runoff losses from land-applied poultry litter with dietary modifications and alum addition. J. Environ. Qual. 33:2210-2216.

Stillborn, H. L., 1997. Progress in development of corn for nutrient potential. Maryland Nutrition Conference. Pages 1-8.

Stillborn, H. L., 1998. Cultivars: Utilizing plant genetics to reduce nutrient loading in the environment. In: Proceedings of the National Poultry Waste Management Symposium. Pages 154-159.

Turek, S. L., 1984. Mineralization of bone. In: Orthopedics: Principles and Their Applications Vol. I. J. B. Lippincot, Philadelphia, PA. pp 164-179.

Van der Klis, J. D., H. A. J. Versteegh, P. C. M. Simons, and A. K. Kies, 1997. The efficacy of phytase in corn-soybean meal-based diets for laying hens. Poult. Sci. 76:1535-1542.

Von Sheuermann, S. E., H. J. Lantzoch, and K. H. Marke, 1998. In vitro and in vivo experiments on the hydrolysis of phytate. Activity of plant phytase. J. Animal Physiology and Animal Nutrition 60:64-75.

Waldroup, P. W., 1999. Nutritional approaches to reducing phosphorus excretion by poultry. Poult. Sci. 78:683-691.

Williams, C. M., J. L. Grimes, D. C. Schwartz, R. L. Mikkelsen, and R. G. McBride, 1996. The use of poultry litter as a source of nitrogen and phosphorus for the biodegradation of petroleum hydrocarbons in contaminated soil. in: Proceedings of 1996 National Poultry Waste Management Symposium. P. H. Patterson and J. P. Blake, eds., Harrisburg, PA.

Wise, A., 1983. Dietary factors determining the biological activities of phytase. Nutrition Abstracts and Reviews. 53:791-806.

Yan, F., C, A, Fritts, P. W. Waldroup, H. L. Stillborn, D. Rice, R. C. Crum, Jr. and V. Raboy, 2003. Comparison of normal and high available phosphorus corn with and without phytase supplementation in diets for male large white turkeys grown to market weights. International Journal of Poultry Science 2 (2): 83-90.

Yi, Z., E. T. Kornegay, V. Ravindran, and D. M. Denbow, 1996. Improving phytate phosphorus availability in corn and soybean meal for broilers using microbial phytase and calculation of phosphorus equivalency values for phytase. Poult. Sci. 75:240-249.

Zublena, J. P., 1994. Excess soil levels of copper, zinc, and phosphorus due to poultry manure application. In: Proceedings of the 21st Annual Carolina Poultry Nutrition Conference. Carolina Feed Industry Association, Charlotte, NC.

MANUSCRIPT I. THE USE OF DEGERMED-DEHULLED CORN TO REDUCE PHOSPHORUS EXCRETION FROM POULTS RAISED TO 21 DAYS OF AGE.

ABSTRACT

An experiment was conducted to determine the effects of feeding degermed-dehulled corn and lower dietary phosphorus (P) on turkey poults raised to 21 days (d) of age. Two hundred and sixteen British United Turkeys were housed in Petersime batteries (six birds per pen) on day of hatch. There were six treatments with six pens per treatment. Poults were fed a starter ration with treatments as follows: 1) normal corn (NC) plus calcium (Ca) and phosphorus (P) at 15% above National Research Council (NRC) levels (NC 115), 2) NC plus Ca and P at NRC levels (NC 100), 3) NC plus Ca and P at 15% below NRC levels (NC 85), 4) degermed-dehulled corn (DDC) plus Ca and P at 15% above NRC levels (DDC 115), 5) DDC plus Ca and P at NRC levels (DDC 100), 6) DDC plus Ca and P at 15% below NRC levels (DDC 85). Feed and water were provided *ad libitium* for 21 d of rearing. Diets were fed in mash form. The pen was the experimental unit. The following parameters were reported at 7, 14 and 21 d; individual bird body weight (BW) and feed conversion ration (FCR), by pen. At 21 d, the following parameters were analyzed apparent metabolizable energy (AMEn), apparent nitrogen retention (ANR), toe and tibia ash (%), tibia breaking strength (kg/mm^2), and total P (%) levels in fecal samples. Data was analyzed using regression analysis with a factorial design of the general linear models procedure (SAS, 1992). Means were separated using least squared means procedure for mean BW and FCR. Poults fed diets formulated with DDC had higher mean BW ($P \leq 0.03$; 709 g vs. 659 g) at 21 d and an improved FCR ($P \leq 0.04$; 1.02 vs. 1.06) at 7 d compared to those fed diets formulated with NC regardless of Ca and P level. The interaction of corn source by NRC level significantly affected AMEn and ANR. Feeding DDC 100 resulted in a significantly higher AMEn than all other diets Birds consuming DDC diets had significantly higher ANR than birds consuming NC. Neither toe nor tibia ash were significantly affected by corn type, NRC level, or the interaction of the two. Tibia breaking strength was significantly affected by corn source as well as NRC level. Poults fed DDC had higher tibia breaking strength than those fed NC ($P \leq 0.05$; 10.42 kg/mm^2 vs. 9.69 kg/mm^2). Poults fed 100% and 115% of recommended NRC levels had higher tibia breaking strength than those fed diets containing 85% of recommended NRC levels ($P \leq 0.03$; 100%-10.47 kg/mm^2, 115%-10.37 kg/mm^2 vs. 85%-9.34 kg/mm^2). Fecal P was not affected by corn type; however, it did decrease significantly as NRC recommended Ca and P levels decreased ($P \leq 0.0001$; 1.3%, 1.1%, and 0.9% total P, respectively). In conclusion, replacing NC with DDC resulted in improved growth performance in poults raised to 21 d.

INTRODUCTION

The rise in consolidated feeding operations has resulted in large quantities of manure that must be disposed of in a limited area. Therefore, society is concerned about the contribution of phosphorus (P) runoff from the application of poultry litter to the eutrophication of surface water. This concern has the poultry industry focused on means of reducing fecal P excreted by poultry (Sharpley, 1999; Waldroup, 1999).

Dietary requirements of P and its availability in feedstuffs of plant origin are, therefore, key issues in poultry nutrition. Poultry diets are primarily composed of seed based ingredients. Approximately two-thirds of the P in seed-based feed ingredients is present as phytate, which is poorly available to poultry (NRC, 1988, 1994; Cromwell et al., 1995, 1993; Angel et al., 2002). Monogastric animals such as poultry lack sufficient amounts of endogenous phosphytase in the gastrointestinal tract (GIT) to hydrolyze the phytate molecule and thus excrete much of the plant P consumed in the feed (Sebastian et al., 1998).

This results in the need to add inorganic sources of P such as dicalcium phosphate to satisfy dietary requirements. However, excess addition of inorganic P and undigested phytate P (PP) results in excess P excretion. This may pose an environmental concern, especially in areas of concentrated poultry production. Therefore, many methods in which to maintain production while reducing fecal P are being evaluated. The recent commercial development of phytase enzymes offers promise in reducing P excretion by increasing the ability of poultry to utilize a portion of the phytate bound P (Sebastian et al., 1998; Ravindran et al., 1995). Other approaches to reduce fecal P include feeding closer to recommended NRC levels (Yan et al., 2003), phase feeding (Dhandu and Angel, 2003), developing genetically modified feedstuffs to have highly available P content (Raboy, 1997), and mechanically modified feedstuffs with altered levels of phytate bound P.

In corn, approximately 90% of phytate P is located within the germ portion of the seed and is in a water soluble form (Oberleas and Harland, 1996). Degermed dehulled corn (DDC) is a mechanically altered corn product that provides lower phytate P levels, higher energy content, as well as lower fiber content (Moeser et al., 2002). Degermed dehulled corn is produced by dry milling which involves a series of steps that are designed to physically separate the corn kernel into its anatomical constituents (endosperm, hull, and germ; Moeser et al., 2002). Removal of the germ through dry milling also removes a large portion of the indigestible section of phytate P (Applegate, 2005). The supplementation of DDC for normal corn (NC) might reduce the amount of total P by reducing the phytate bound P in the diet. The objective of this study was to evaluate the use of DDC in diets for turkeys grown to 21 days (d) with respect to growth performance, bone integrity, and fecal P.

MATERIALS AND METHODS

The design of this study was a randomized complete block design (RCB) with a 2X3 factorial arrangement of treatments (two levels of corn and three levels of Ca and P). The experimental period was 21 d. Two hundred and sixteen, one-day old commercial Large White BUTA (Lewisburg, WV), male poults were obtained from a commercial hatchery and randomly assigned to cages. All birds were housed in Petersime (Petersime Incubator Co., Gettysburg, OH) battery cage units within a climate controlled animal room. Each battery contained 24 cages with 12 cages on each side of the battery. The 12 cages per side were considered an experimental block to account for error due to differences in temperature, light, or position. There were six treatments with six pens per treatment. Dietary treatments were randomly assigned to two pens in each block with the pen serving as the experimental unit. There were six birds per pen at day of hatch. All cages contained heating units that were monitored throughout the trial for temperature consistency. Each parameter was regressed on corn, dietary Ca and P levels, and corn X dietary Ca and P levels. Basal diets met or exceeded NRC (1994) nutrient recommendations. The treatment diets utilized one of two types of corn (normal corn and degermed-dehulled corn) and three levels of dietary Ca and P (Table 1.1). Poults were fed a starter ration with treatments as follows: 1) normal corn (NC) plus calcium (Ca) and phosphorus (P) at 15% above recommended NRC levels (NC 115), 2) NC plus Ca and P at recommended NRC levels (NC 100), 3) NC plus Ca and P at 15% below recommended NRC levels (NC 85), 4) degermed dehulled corn (DDC) plus Ca and P at 15% above recommended NRC levels (DDC 115), 5) DDC plus Ca and P at recommended NRC levels (DDC 100), 6) DDC plus Ca and P at 15% below recommended NRC levels (DDC 85). The DDC was milled from the same batch of corn used in treatments 1-3. Diet samples were analyzed by an independent laboratory to determine crude protein, Ca, and total P of formulated diets on an as fed basis (Table 1.1).

Poults received feed and water *ad libitium*. Feed consumption, by pen, and individual body weight (BW) were recorded at 7 day intervals beginning at day of hatch until 21 d. At the end of the study, fecal samples were collected over a three-day period from each treatment to measure AMEn, ANR, and total fecal P. An inert digestible marker, Celite^{TM} (Celite Corp., Lompar, CA), was used to estimate the digestibility of dietary nutrients (Scott and Boldaji, 1997). The phosphorus microtiter assay (Appendix I) was used to determine the P concentration of total fecal P samples.

On d 21, one bird per pen was necropsied and the tibias removed. The left tibia and left middle toe were used for ash (%) determination of dry, fat free bone as described by AOAC (1990). The left tibia was stripped of all soft tissue, fat extracted, oven dried for 24 h at 100°C and then ashed in a muffle furnace at 600°C for 24 h to determine tibia ash, expressed as percent of dry weight. The right tibia was used to determine breaking strength according to procedures documented in Roberson et al., (2004). Physical bone characteristics were determined by the three-point bending test. The load and the stress at failure, the strain and the Young's modulus (modulus of elasticity) were determined using a three-point flexural bending with a total distance of 40 mm between the two supporting ends. The load is defined as force in kilograms per square millimeter of cross-sectional area and represents bone strength. The modulus measures the stiffness of the bone as it relates to stress and strain (Rath et al., 1999). Stress signifies internal resistance to deformity and strain characterizes the percentage of deformity (Einhorn, 1996). The rate of loading was kept constant at 10 mm/min.

Percentage data were subjected to arcsin transformation of the square root before analysis; however, actual percentage means are presented. Differences among treatment means were partitioned using the least square means procedure of SAS (SAS Institute, Inc., 1992). Statements of significance are based on $P \leq 0.05$ unless otherwise stated.

RESULTS AND DISCUSSION

Poults fed DDC had an increased mean BW (709 g vs. 659 g) at 21 d compared to those fed NC (Table 1.2). This improvement agrees with Applegate (2005) who reported chicks fed DDC diets were significantly heavier at 17 (501 g) and 31 (1380 g) d. In contrast, Yan et al. (2003) reported no significant differences at 4 wk in the body weights of male Large White turkeys fed normal corn (971 g) or genetically modified highly available P corn (990 g). In the current study, poults fed 115%, 100%, and 85% of recommended NRC Ca and P levels regardless of corn type performed at a similar rate. Bailey et al., (1986) reported body weight was not significantly affected by the level of dietary phosphorus consumed by 1 or 3 wk poults when available P was varied from 0.35% to 1.15%. Potter (1988) reported that the available P requirement for optimum body weight gain of turkey poults (0 to 4 wk) is 0.41%. Therefore, diets containing recommended NRC Ca and P levels 15% below recommended levels would be sufficient to maintain growth.

Poults fed DDC had a significantly lower feed conversion (1.02 vs. 1.06) (Table 1.3) at 7 d than those fed NC regardless of Ca and P level. However, this affect was not maintained through the subsequent weeks of the trial. Feed consumption was relatively consistent throughout our study, as was observed by others (Yan et al., 2003; Applegate, 2005).

Tibia and toe ash, breaking strength and fecal samples are ways in which to measure the level of P used, stored, and excreted by the bird. Toe ash is a reliable measurement of P status and accurate in determining P availability for poultry (Waldroup, 1999; Potter, 1995). In the current study, neither toe nor tibia ash were significantly affected by corn type, NRC level, or their interaction (Table 1.4). In contrast birds fed genetically modified high available P corn (47.51%) had significantly higher tibia ash content at 4 wk versus feeding normal corn (46.52%) (Yan et al., 2003). They also noted that a reduction in dietary nonphytate phosphorus levels below NRC (1994) recommendations generally did not impair tibia ash content until reduced to 0.15% below NRC recommendations. The consistent effect of feeding turkey poults lower levels of nonphytate P (0.48%) on tibia ash at 15 and 28 d confirms that the P requirement for mineralization of bone is higher than for growth in turkey poults (Charbeneau and Roberson, 2004). Bailey et al., (1986) also showed the level of available phosphorus had a significant effect on the tibia ash of poults at 1 and 3 wk. Poults fed 0.75%, 0.95%, and 1.15% available P at 1 wk had significantly higher tibia ash then those fed 0.35 and 0.55% available P. However at 3 wk, poults fed 0.55%, 0.75%, 0.95%, and 1.15% available P had significantly higher tibia ash then those fed 0.35%

available P. Potter (1988) reported that the available P requirement for optimum bone mineralization of the turkey poults (0 to 3 wk) is 0.41%. Because bone mineralization provides compressional strength to bone, the bone ash content has been used as an index of bone strength (Rath et al., 2000). This along with results reported by Bailey et al., (1986) and Charbeneau and Roberson (2004) support the current findings where birds fed available P levels 15% below the recommended NRC levels supported both growth and bone mineralization.

Bone strength is the ability to endure stress; therefore it is related to ultimate load or stress at which the bone will break (Rath et al., 2000). The load at break is the sum of all forces and moments applied to the bone and is the breaking strength of the bone (Nigg and Grimstone, 1994). In three-point bending tests, the bone undergoes elastic deformation until the point is reached where it is not longer resilient (Rath et al., 2000). The load required to reach this point is called yield strength or stress at yield (Turner and Burr, 1993). Poults fed DDC had a higher tibia breaking strength than those fed NC ($P \leq 0.05$; 10.42 kg/mm^2 vs. 9.69 kg/mm^2; Table 1.4). Poults fed 100% and 115% of NRC recommended Ca and P levels had higher tibia breaking strength than those fed diets containing 85% of NRC recommended Ca and P levels (100%-10.47 kg/mm^2, 115%-10.37 kg/mm^2 vs. 85%-9.34 kg/mm^2; Table 1.4).

At the end of the trial fecal samples were collected for a three day period from each treatment to determine AMEn, ANR and total fecal P. The AMEn and ANR were significantly affected by the interaction of corn source and NRC level. There was a significantly linear increase in AMEn as NRC recommended Ca and P levels decreased when fed NC (NC 85-4,117 kcal/kg, NC 100-3,917 kcal/kg, NC 115-3,485 kcal/kg; Figure 1.1). In comparing DDC as a replacement for corn in turkey starter diets, Applegate (2005) reported the AMEn of male chicks raised to 14 d to be significantly greater when fed DDC (3,346 kcal/kg) versus normal corn (3,235 kcal/kg). Moeser et al. (2002) noted a numerically higher ME (3,517 kcal/kg) in growing pigs when DDC was the grain source versus NC (3,447 kcal/kg). In this study, increasing the dietary P content consistently lowered the AMEn values of the diets containing NC. The phenomenon of reduced dietary AMEn with the addition of inorganic phosphates is well known and is generally attributed to the 'dilution effect' of added inorganic phosphates (Ravindran et al., 2000). However, this cannot explain the observed AMEn results of diets containing DDC and increasing levels of P. The fact that the negative effects on AMEn were overcome suggests that phytate complexes may be partly responsible for the observed depressions in AMEn values. Perhaps the ratio of Ca to P in adequate diets leads to the formation of insoluble Ca-P complexes thereby contributing to the observed effects.

ANR increased as NRC Ca and P levels decreased regardless of corn type with NC having a greater decrease (DDC 85-91.6%, DDC 100-90.2%, DDC 115-87.9%, versus NC 85-83.3%, NC 100-79.7%, NC 115-61.8%; Figure 1.2). Similarly, Moeser et al. (2002) noted in growing pigs a 16% improvement in ANR when DDC (93.6%) was fed as a replacement for corn (78.4%). These results were in contrast to that reported by Applegate (2005) who reported ANR was not affected by corn source (DDC versus corn) at any age.

In the current study, dietary P levels significantly affected fecal P. While fecal P was not affected by corn type, it did decrease significantly as NRC levels decreased from 115% to 85% of recommended NRC levels (Table 1.5). This agrees with findings made by Slaugh et al., (1989) who reported fecal levels increased from 1.93% to 3.10% as the level of P increased from 0.15% to 0.70% available P. Poults fed P levels below NRC excreted less total fecal P than all other treatments. Therefore formulating diets with low levels of dietary P will decrease the amount of fecal P excreted by the poult lowering the environmental impact in areas of highly concentrated animal production. This might aid in the reduction of P runoff by application of turkey litter to land. The inclusion of DDC had no adverse effects on performance and could contribute further to reduction of P in the excreta.

In conclusion, replacing NC with DDC resulted in improved performance in poults raised to 21 d. There was not a reduction in fecal P when feeding DDC despite improvements in tibia breaking strength. However, P may be overfed when fed at levels of 0.6% or 0.7% aP. Poults fed Ca and P levels 15% below NRC demonstrated decreased levels of both total fecal P while maintaining growth parameters although bone development was decreased. Yan et al., (2003) suggests that NRC (1994) recommendations for P are more than adequate for turkeys. From the results of this study, one might further conclude that the NRC recommended levels of dietary P supports growth of turkey poults; however, additional reductions in dietary total P may be possible. Further research to ascertain the required levels of dietary P (total and available) are needed for the varied conditions under which turkey poults are reared. This could have significant implications for turkey production as total fecal P would be reduced when fed lower than recommended NRC P levels or when total dietary P is reduced.

REFERENCES

Angel, R., N. M. Tamin, T. J. Applegate, A. S. Dhandu, and L. E. Ellestad, 2002. Phytic acid chemistry: Influence on phytin phosphorus availability and phytase efficacy. J. Appl. Poult. Res. 11:471-480.

Applegate, T. J., 2005. The nutritional value of dehulled-degermed corn for broiler chickens and its impact on nutrient excretion. Poult. Sci. 84:742-747.

AOAC. 1990. Official Methods of Analysis. (15th ed.) Assoc. Offic. Anal. Chem., Arlington, VA.

Bailey, C. A., S. Linton, R. Brister, and C. R. Creger, 1986. Effects of graded levels of dietary phosphorus on bone mineralization in the very young poult. Poult. Sci. 65:1018-1020.

Charbeneau, R. A. and K. D. Roberson, 2004. Effects of corn and soybean meal particle size on phosphorus use in turkey poults. J. Appl, Poult. Res. 13:302-310.

Cromwell, G. L., 1993. An assessment of the bioavailability of phosphorus in feed ingredients for nonruminants. Proc. Maryland Nutr. Conf., Baltimore, MD pp. 146.

Cromwell, G. L., R. D. Coffer, G. R. Parker, H. J. Monegue, and J. H. Randolph, 1995. Efficacy of a recombinant-derived phytase in improving the bioavailability of phosphorus in corn-soybean meal diets for pigs. J. Anim. Sci. 73:2000-2008.

Dhandu, A. S. And R. Angel, 2003. Broiler nonphytin phosphorus requirement in the finisher and withdrawal phases of a commercial four-phase feeding system. Poult. Sci. 82:1257-1265.

Moeser, A. J., I. B. Kim, E. van Heugten, and T. van Kempen, 2002. The nutritional value of degermed, dehulled corn for pigs and its impact on the gastrointestinal tract and nutrient excretion. J. Anim. Sci. 80:2629-2638.

National Research Council, 1988. Nutrient requirements of poultry. 8th rev. ed. National Academy Press, Washington, DC.

National Research Council, 1994. Nutrient requirements of poultry. 9th rev. ed. National Academy Press, Washington, DC.

Nigg, B. M., and S. K. Grimstone, 1994. Bone. Pages 48-78 *in*: Biomechanics of Musculoskeletal System. B. M. Nigg and W. Herzog, ed. John Wiley & Sons, New York, NY.

Oberleas, D. and Harland, F. 1996. Impact of phytate on nutrient availability, In: *Phytase in Animal Nutrition and Waste Management* (Coelho, M. B. and Kornegay, E. T., Eds), BASF Corporation, Mount Olive, NJ.

Potter, L. M. 1988. Bioavailability of phosphorus from various phosphates based on body weight and toe ash measurements. Poultry Science 67:96-102.

Potter, L. M., M. Potchanakorn, V. Ravindran, and E. T. Kornegay, 1995. Bioavailability of phosphorus in various phosphate sources using body weight and toe ash as response criteria. Poultry Sci. 74:813-820.

Peeler, H. T., 1972. Biological availability of nutrients in feeds: availability of major mineral ions. J. Anim. Physiology and Animal Nutrition Sci. 35:695-699.

Raboy, V., 1997. Accumulation and storage of phosphate and minerals. Pages 441-477 in: Advances in Cellular and Molecular Biology of Plants. Vo. 4. Cellular and Molecular Biology of Plant Seed Development. B. A. Larkins and I. K. Vasil, ed. Kluwer Publishers, Dordrecht, The Netherlands.

Rath, N. C., G. R. Huff, W. E. Huff, and J. M. Balog, 2000. Factors regulating bone maturity and strength in poultry. Poult. Sci. 79:1024-1032.

Ravindran, V, E. T. Kornegay, D. M. Denbow, Z. Yi, and R. M. Hulet, 1995. Response of turkey poults to tiered levels of Natuphos phytase added to soybean meal-semi-purified diets containing three levels of nonphytate phosphorus. Poultry Sci. 68:1843-1854.

Ravindran, V, S. Cabahug, G. Ravindran, P. H. Selle, and W. L. Bryden, 2000. Response of broiler chickens to microbial phytase supplementation as influenced by dietary phytic acid and non-phytate phosphorus levels. II. Effects on apparent metabolisable energy, nutrient digestibility and nutrient retention. British Poultry Sci. 41:193-200.

Roberson, K. D. M. W. Lunzinger, and R. A. Charbeneau 2004. Benefit of feeding dietary calcium and nonphytate phosphorus levels above National Research Council recommendations to tom turkeys in the growing-finishing phases. Poultry Sci. 83:689-695.

SAS Institute, 1992. SAS User's Guide. Version 6.08. SAS Institute Inc., Cary, NC.

Scott, T. A., and F. Boldaji, 1997. Comparison of inert markers [chromic oxide or insoluble ash (Celite ™)] for determining apparent metabolizable energy of wheat- pr barley-based broiler diets with or without enzymes. Poult Sci. 76:594-598.

Sebastian, S., D. P. Touchburn, and E. R. Chavez, 1998. Implications of phytic acid and supplemental microbial phytase in poultry nutrition: a review. World's Poultry Sci. J. 54:27-47.

Sharpley, A., 1999. Symposium: Reducing the environmental impact of poultry production: Focus on phosphorus. Poult. Sci. 78:660-673.

Slaugh, B. T., N. P. Johnston, and J. D. Pattern, 1989. Research Note: Effect of dietary phosphorus levels on performance of turkey breeder hens. Poultry Sci. 68:319-322.

Turner, C. H., and D. B. Burr, 1993. Basic biomechanical measurements of bone. A tutorial. Bone 14:595-608.

Waldroup, P. W., 1999. Nutritional approached to reducing phosphorus excretion by poultry. Poultry Sci. 78:683-691.

Yan, F., C, A, Fritts, P. W. Waldroup, H. L. Stilborn, D. Rice, R. C. Crum, Jr. and V. Raboy, 2003. Comparison of normal and high available phosphorus corn with and without phytase supplementation in diets for male large white turkeys grown to market weights. International Journal of Poultry Science 2 (2): 83-90.

Table 1.1. Dietary treatments[1] fed to turkey poults from day of hatch to 21 days of age.

Ingredient (%)	NC 115	NC 100	NC 85	DDC 115	DDC 100	DDC 85
Corn Source	44.0	44.0	44.0	40.0	40.0	40.0
Soybean Meal	40.0	40.0	40.0	42.0	42.0	42.0
Poultry Meal	8.00	8.00	8.00	8.00	8.00	8.00
Limestone	1.60	1.31	1.05	1.60	1.15	0.90
Dicalcium Phosphate	2.40	1.81	1.20	2.60	2.00	1.40
Poultry Fat	2.50	2.50	2.50	2.50	2.50	2.50
DL-Methionine	0.22	0.22	0.22	0.21	0.21	0.21
Salt	0.30	0.30	0.30	0.30	0.30	0.30
Minerals (TM-90)[2]	0.20	0.20	0.20	0.20	0.20	0.20
Vitamins (NCSU-90)[3]	0.10	0.10	0.10	0.10	0.10	0.10
Selenium Supplement[4]	0.20	0.20	0.20	0.20	0.20	0.20
Sand		0.90	1.70	2.20	3.30	4.00
Celite	1.0	1.0	1.0	1.0	1.0	1.0
Total	100	100	100	100	100	100
Calculated Analysis						
Crude Protein, %	28	28	28	28	28	28
M. E. (kcal/kg)	2,800	2,800	2,800	2,800	2,800	2,800
Calcium, %	1.5	1.3	1.1	1.5	1.3	1.1
Phosphorus (total), %	1.0	0.9	0.8	0.9	0.9	0.8
Phosphorus (available), %	0.7	0.6	0.5	0.7	0.6	0.5
Lysine, %	1.8	1.8	1.8	1.8	1.8	1.8
DL-Methionine, %	0.7	0.7	0.7	0.7	0.7	0.7
Analyzed						
Crude Protein, %	29.0	28.0	27.0	28.0	28.0	28.0
Calcium, %	1.2	1.0	0.95	2.1	1.3	0.94
Phosphorus (total), %	1.1	0.8	0.74	1.0	0.8	0.72

[1]Normal Corn (NC) + 15% Above NRC (115), Normal Corn (NC) + NRC (100), Normal Corn (NC) + 15% Below NRC (85), Degermed-Dehulled Corn (DDC) + 15% Above NRC (115), Degermed-Dehulled Corn (DDC) + NRC (100), Degermed-Dehulled Corn (DDC) + 15% Below NRC (85).

[2]Mineral composition (in g/kg of diet): zinc sulfate, 120; manganous sulfate, 120; copper sulfate, 10; calcium iodate, 2.5; colbalt sulfate, 1.0.

[3]Vitamins in amounts per kilogram of diet; vitamin A, 26,400 IU; vitamin D_3, 8,000 IU; vitamin E 132 IU; vitamin B_{12}, 79.2 µg; riboflavin 26.4.

[4]Provided 0.3 mg Se per kilogram of diet.

Table 1.2. Mean body weights (g) of male turkey poults fed dietary treatments[1] to 21 days (d) of age.

	Mean Body Weight (g)[2]		
Treatment	7 d	14 d	21 d
NC	151.06	358.49	659.75[b]
DDC	153.89	375.79	709.05[a]
P-value			0.03
115	148.49	354.92	673.45
100	154.19	379.05	703.54
85	154.76	367.45	676.20
SEM	4.05	12.58	25.88

[1] Normal Corn (NC) + 15% Above NRC (115), Normal Corn (NC) + NRC (100), Normal Corn (NC) + 15% Below NRC (85), Degermed-Dehulled Corn (DDC) + 15% Above NRC (115), Degermed-Dehulled Corn (DDC) + NRC (100), Degermed-Dehulled Corn (DDC) + 15% Below NRC (85).

[2] SEM

[a, b] At 21 days of age there was a corn source effect ($P \leq 0.03$). Poults fed DDC had a higher average body weight than poults fed NC.

Table 1.3. Feed conversion ratios of turkey poults fed dietary treatments[1] to 21 days (d) of age.

	Feed Conversion Ratio[2]			
Treatment	7 d	14 d	21 d	Cumulative 0-21 d
NC	1.06[a]	1.25	1.67	1.43
DDC	1.02[b]	1.22	1.48	1.31
P-value	0.04			
115	1.04	1.24	1.48	1.32
100	1.05	1.22	1.58	1.36
85	1.04	1.25	1.66	1.43
SEM	0.02	0.02	0.17	0.08

[1] Normal Corn (NC) + 15% Above NRC (115), Normal Corn (NC) + NRC (100), Normal Corn (NC) + 15% Below NRC (85), Degermed-Dehulled Corn (DDC) + 15% Above NRC (115), Degermed-Dehulled Corn (DDC) + NRC (100), Degermed-Dehulled Corn (DDC) + 15% Below NRC (85).

[2] SEM

[a, b] At 7 days of age there was a corn source effect ($P \leq 0.04$). Poults fed DDC had a lower feed to gain ratio than poults fed NC.

Table 1.4. Toe ash (%), tibia ash (%), and tibia breaking strength (kg/mm^2) measured at 21 days of age in male turkey poults fed dietary treatments[1].

Treatment	Toe Ash (%)[2]	Tibia Ash (%)[3]	Tibia Breaking Strength (kg/mm^2)[4]
NC	9.56	53.39	9.69[b]
DDC	10.04	56.04	10.42[a]
P-value			0.05
115	9.81	57.32	10.37[a]
100	10.42	54.96	10.47[a]
85	9.17	51.86	9.34[b]
P-value			0.03
SEM	0.76	3.98	0.44

[1] Normal Corn (NC) + 15% Above NRC (115), Normal Corn (NC) + NRC (100), Normal Corn (NC) + 15% Below NRC (85), Degermed-Dehulled Corn (DDC) + 15% Above NRC (115), Degermed-Dehulled Corn (DDC) + NRC (100), Degermed-Dehulled Corn (DDC) + 15% Below NRC (85).

[2] SEM

[3] SEM

[4] SEM

[a, b] Means within a treatment and column lacking a common superscript differ significantly ($P \leq 0.05$).

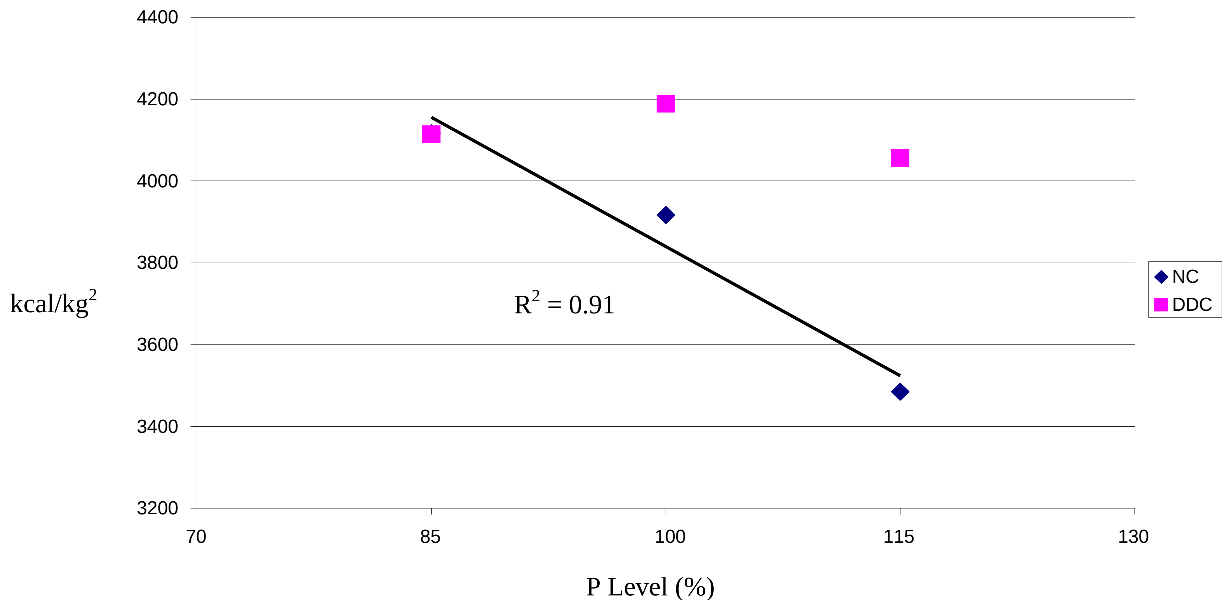
Table 1.5. Total fecal P (%) measured at 21 days of age in male turkey poults fed dietary treatments[1].

Treatment	Total Fecal P (%)[2]
NC	1.1
DDC	1.1
115	1.3[a]
100	1.1[b]
85	0.9[c]
P-value	0.0001
SEM	0.06

[1] Normal Corn (NC) + 15% Above NRC (115), Normal Corn (NC) + NRC (100), Normal Corn (NC) + 15% Below NRC (85), Degermed-Dehulled Corn (DDC) + 15% Above NRC (115), Degermed-Dehulled Corn (DDC) + NRC (100), Degermed-Dehulled Corn (DDC) + 15% Below NRC (85).

[2] SEM

[a-c] Means lacking a common superscript differ significantly ($P \leq 0.05$).

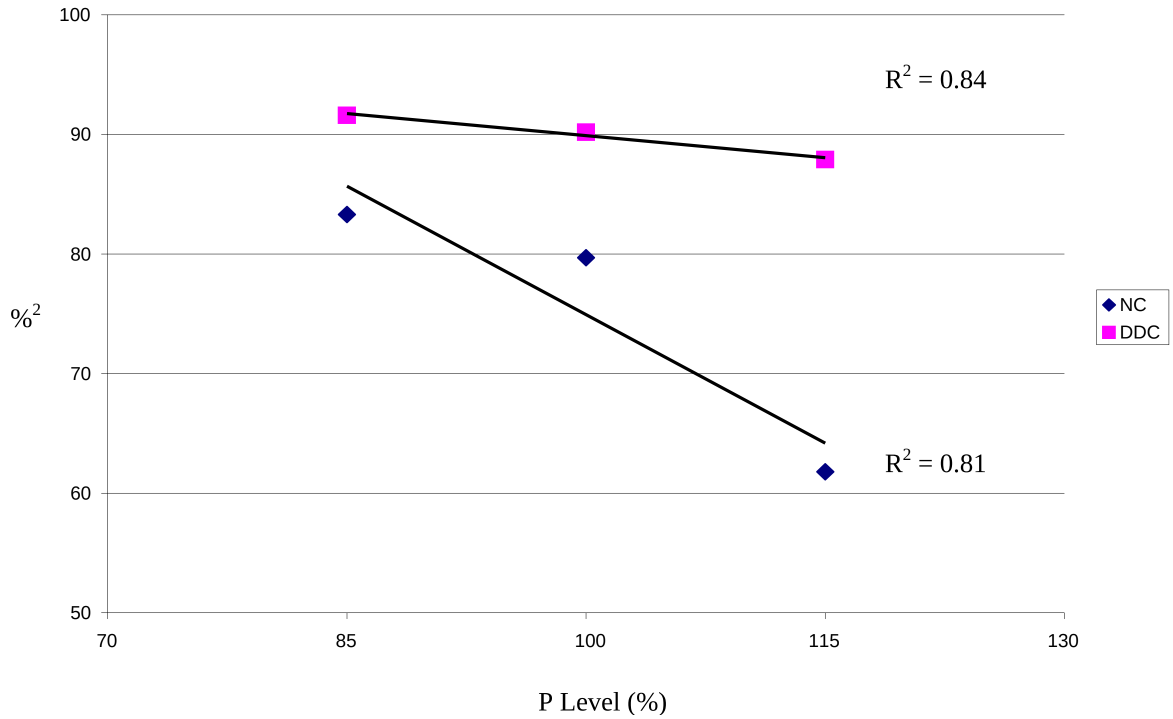


NC P = 0.0001 Y = -21.1 (x) + 5632
DDC P = 0.8 Not Linear

Figure 1.1. AMEn (kcal/kg) of turkey poults fed dietary treatments[1] to 21 days of age.

[1] Normal Corn (NC) + 15% Above NRC (115), Normal Corn (NC) + NRC (100), Normal Corn (NC) + 15% Below NRC (85), Degermed-Dehulled Corn (DDC) + 15% Above NRC (115), Degermed-Dehulled Corn (DDC) + NRC (100), Degermed-Dehulled Corn (DDC) + 15% Below NRC (85).

[2] SEM = 19.67



NC	P = 0.0001	y = -0.71 (x) + 136
DDC	P = 0.0001	y = -0.12 (x) + 100

Figure 1.2. ANR (%) of turkey poults fed dietary treatments[1] to 21 days of age.

[1] Normal Corn (NC) + 15% Above NRC (115), Normal Corn (NC) + NRC (100), Normal Corn (NC) + 15% Below NRC (85), Degermed-Dehulled Corn (DDC) + 15% Above NRC (115), Degermed-Dehulled Corn (DDC) + NRC (100), Degermed-Dehulled Corn (DDC) + 15% Below NRC (85).

[2] SEM = 0.83

MANUSCRIPT II. THE USE OF LOW-PHYTATE SOYBEAN MEAL TO REDUCE PHOSPHORUS EXCRETION FROM POULTS RAISED TO 18 DAYS OF AGE.

ABSTRACT

An experiment was conducted to determine if feeding genetically modified low-phytate soybean meal (LP SBM) to turkey poults would support growth performance as well or better than those fed diets containing normal soybean meal (SBM) and would reduce phosphorus (P) excretion from poults raised to 18 days (d) of age. Day of hatch Nicholas Large White male turkey poults (144) were housed in a Petersime battery comprised of 24 pens with six birds per pen. There were four treatments with six pens per treatment. Four turkey starter rations were fed to poults in mash form as follows: 1) SBM plus Ca and P at 15% above recommended NRC levels (SBM 115), 2) LP SBM plus Ca and P at 15% above recommended NRC levels (LP SBM 115), 3) LP SBM plus Ca and P at recommended NRC levels (LP SBM 100), 4) LP SBM plus Ca and P at 15% below recommended NRC levels (LP SBM 85). Feed and water were provided *ad libitium*. Individual BW, feed consumption (by pen), and feed conversion (FCR, calculated) where determined at 6 d intervals to 18 d. The following parameters were also measured at 18 d: toe and tibia ash (%), tibia P (%), tibia breaking strength, apparent metabolizable energy (AMEn), apparent nitrogen retention (ANR) and P (%) levels in fecal samples. There were no significant differences in mean BW, FCR, or cumulative FCR when poults were fed diets formulated with LP SBM compared to those fed diets formulated with SBM. Neither toe, tibia ash, or tibia P were significantly

affected by SBM type, NRC level, or the interaction of the two. There was a significant linear decrease in tibia breaking strength as diets containing LP SBM decreased in recommended Ca and P NRC levels 115%, 100% and 85% below NRC ($P \leq 0.05$; 11.26 kg/mm^2, 10.89 kg/mm^2, 10.28 kg/mm^2; respectively). There was a significant linear increase in AMEn and ANR as diets containing LP SBM decreased in recommended Ca and P NRC levels. Fecal phosphorus decreased as NRC recommended Ca and P levels decreased in LP SBM diets. Total fecal P was significantly higher when poults were fed SBM 115 versus LP SBM 115. In conclusion, replacing normal SBM with LP SBM resulted in equal growth performance and decreased fecal P in poults raised to 18 d.

INTRODUCTION

In the US, more than 50% of all soybean meal (SBM) produced is utilized by poultry (Baker, 2000). Soybean meal is commonly added to poultry diets as a source of high-quality protein. Typical poultry diets consist of corn and SBM to provide adequate nutrition to support growth. However, a considerable amount of phosphorus (P) in poultry diets is in the form of phytate P. Approximately 55% to 60% of the total P found in soybeans is bound to phytate (Eeckhout and Paepe, 1994; Ravindran et al., 1995). Phytate is an organically bound storage form of P that is poorly digested by poultry. Poultry possess insufficient amounts of endogenous phytase to liberate substantial quantities of P from the phytate compound (Maenz and Classen, 1998). For these reasons, diets are typically supplemented with inorganic P to meet the nutritional requirements of the bird. However, inclusion of supplemental P in excess of the birds' optimal requirement for P may lead to the increased excretion of dietary P. The accumulation of P in the environment can lead to eutrophication of fresh waters; therefore, P is classified as an environmental pollutant (Honeyman, 1993). To help mitigate excess P in the environment, many suggest that the poultry industry should examine the development of new production and feeding methods that maintain productivity while meeting environmental regulations.

Phosphorus excretion has made it necessary to look at other methods in which to reduce the amount of phosphorus that is being unutilized by poultry. Methods that have been discussed include formulating diets closer to the recommended nutritional requirements, by including phytase as well as genetically and mechanically altered feed ingredients. Nelson et al. (1968, 1971) demonstrated that the addition of phytase to broiler diets improved the availability of phytate-bound phosphorus. Turkey poults respond favorably to the addition of phytase to diets low in phosphorus (Ravindran et al., 1995; Qian et al., 1996). Another approach to reducing the environmental impact of P is the use of genetically modified feedstuffs that contain lower levels of phytate P. Characteristically these varieties possess more available P (aP), also known as non phytate P (nPP), when compared to conventional varieties (Wilcox et al., 2000; Raboy et al., 2001; Raboy, 2002). The relative bioavailability of P from low-phytate SBM was 15% to 25% higher compared with conventional SBM when fed to broiler chickens (Sands et al., 2003), and total P excretion decreased when feeding low-phytate SBM to swine (Powers et al., 2006). Soybean meal makes up a very large portion of turkey starter diets; therefore, the use of LP SBM in these diets may lead to significant reductions in turkey P excretion. The objective of this study was to determine the effect of feeding LP SBM with varying recommended NRC levels of Ca and P on performance and fecal P excretion for male turkeys grown to 18 d.

MATERIALS AND METHODS

One-day old commercial Nicholas Large White (Aviagen Turkeys, Lewisburg, WV) male poults were obtained from a commercial hatchery (Sleepy Creek Hatchery, Goldsboro, NC) and randomly assigned to cages. All birds were housed in Petersime battery cage units within a climate-controlled animal room. The design of this study was a randomized complete block design (RCB) with four treatments with six replicate pens per treatment. The four dietary treatments were typical corn-soy based diets meeting NRC (1994) nutrient recommendations for starting turkeys (Table 2.1). The treatment diets were as follows: 1) SBM plus Ca and P at recommended NRC levels (SBM 115), 2) LP SBM plus Ca and P at 15% above recommended NRC levels (LP SBM 115), 3) LP SBM plus Ca and P at recommended NRC levels (LP SBM 100), 4) LP SBM plus Ca and P at 15% below recommended NRC levels (LP SBM 85). Diets were analyzed by an independent laboratory to determine crude protein, Ca, and total P of formulated diets on an as fed basis (Table 2.1). Poults received feed and water *ad libitium*. An indigestible marker, Celite™ (Celite Corp., Lompar, CA), was added to each diet to estimate the digestibility of dietary nutrients (Scott and Boldaji, 1997).

Feed consumption, by pen, and individual body weights (BW) were recorded at 6 d intervals until 18 d. On day 18, two birds per pen were necropsied and the tibias removed. The right tibia was used to determine breaking strength. The right middle toe was used to determine percent toe ash. The left tibias were used for ash determination of dry fat free bone as described by AOAC (1990). The left tibias were stripped of all soft tissue, fat extracted, oven dried for 24 h at 100°C and then ashed in a muffle furnace at 600°C for 24 h to determine tibia ash, expressed as percent of dry weight. Ashed samples were then ground in order to determine percent P. Fecal samples were collected over a three-day period from each treatment to measure AMEn, ANR, and total fecal P. The ratio of the marker in the diet to the amount of marker in the excreta was used to calculate the digestibility of the diet. The phosphorus microtiter assay (Appendix I) was used to determine the P concentration of diet and total fecal P samples.

Data were analyzed using the General Linear Model (GLM) procedures (SAS Institute, Inc., 2000). Differences among treatment means were partitioned using the least squares means procedure of SAS (SAS Institute, Inc., 2000). For soybean meal effect, parameters of birds fed SBM 115 were compared to parameters of birds fed LP SBM 115. For Ca and P level effect, parameters of birds fed differing levels of Ca and P within LP SBM were compared. Statements of significance are based on $P \leq 0.05$ unless otherwise stated.

RESULTS AND DISCUSSION

Body weight gain and FCR were not significantly affected by soybean meal type (SBM 115 vs LP SBM 115) or recommended NRC Ca and P levels within LP SBM (Table 2.2). These findings are consistent with other reports concerning the use of high available P corn in poultry (Huff et al., 1998; Snow et al., 2003) and low-phytate corn, barley, and soybeans in swine (Powers et al., 2006; Spencer et al., 2000).

Bone strength is the ability to endure stress; therefore it is related to ultimate load or stress at which the bone will break (Rath et al., 2000). The load at break is the sum of all forces and moments applied to the bone and defines the breaking strength of the bone (Nigg and Grimstone, 1994). In three-point bending tests, the bone undergoes elastic deformation until the point is reached where it is not longer resilient (Rath et al., 2000). The load required to reach this point is called yield strength or stress at yield (Turner and Burr, 1993). At the end of this study, two birds per treatment were used to determine tibia and toe ash (%), tibia P (%) (Table 2.3) and tibia breaking strength (kg/mm^2) (Figure 2.1). Percent tibia ash, percent toe ash and percent tibia P were not significantly affected by soybean meal type or Ca and P levels. Tibia breaking strength was not significantly affected by treatment; however, there was a significantly linear decrease in tibia breaking strength as Ca and P levels decreased in the diets containing LP SBM. These results agree with those of Roberson et al., (2000) and Thompson et al., (2002), who reported impaired bone mineralization when birds were fed 75% to 83% of NRC recommended nPP levels, respectively, which is lower than the nPP level used in the current study. In contrast, Potter (1990) reported that the aP requirement for optimum bone mineralization of the young turkey was 0.41%. Similarly, Atia et al., (2000) fed 73% of NRC with 100% Ca and reported bone ash, strength, and density were similar to the control diet of 110% NRC Ca and nPP. However, when feeding nPP at 52% of NRC and 90% Ca, bone ash, density, and strength measurements were substantially lower.

At the end of the study, fecal samples were collected for three days to determine AMEn (Figure 2.2), ANR (Figure 2.3) and total fecal P content (Table 2.3). The ANR was not significantly affected by treatment; however, there was a significantly linear increase in ANR as Ca and P decreased in the diets containing LP SBM. The AMEn was significantly higher when poults were fed LP SBM 100 and LP SBM 85. Fecal P was significantly lower when poults were fed LP SBM 115 versus SBM 115. This was similar to results in other studies where the impact of reducing dietary P on total P excretion was examined. Wienhold and Miller (2004) reported a decrease of total fecal P when swine were fed LP SBM. Jang et al., (2003) and Penn et al., (2004) reported a decrease in total P excretion when poultry were fed low-phytate corn versus normal corn. In conclusion, feeding LP SBM resulted in poult performance equal to SBM and reduced fecal P.

REFERENCES

Angel, C. R., W. J. Powers, T. J. Applegate, N. M. Tamim, and M. C. Christman, 2005. Influence of phytase on water soluble phosphorus in poultry and swine manure. J. Environ. Qual. 34:563-571.

AOAC. 1990. Official Methods of Analysis. 15th ed. Association of Official Analytical Chemists. Arlington, VA.

Applegate, T.J., B. C. Joern, D. L. Nussbaum-Wagler, and R. Angel, 2003. Water-soluble phosphorus in fresh broiler litter is dependent upon phosphorus concentration fed but not on fungal phytase supplementation. Poult. Sci. 82:1024-1029.

Atia, F. A., P. E. Waibel, I. Hermes, C. W. Carlson, and M. M. Walser, 2000. Effect of dietary phosphorus, calcium, and phytase on performance of growing turkeys. Poult. Sci. 79:231-239.

Baker, D. H., 2000. Nutritional constraints to use of soy products by animals. in: Soy in Animal Nutrition. J. K. Drackley, ed. Federation of Animal Science Societies, Savoy, IL. pp.1-12.

Eeckhout, W. and M. De Paepe, 1994. Total phosphorus, phytate-phosphorus and phytase activity in plant feedstuffs. Animal Feed Science and Technology 47:19-29.

Honeyman, M. S., 1993. Environment-friendly swine feed formulation to reduce nitrogen and phosphorus excretion. Am. J. Alternative Agr. 8:128-132.

Huff, W. E., P. A. Moore Jr., P. W. Waldroup, A. L. Waldroup, J. M. Balog, G. R. Huff, N. C. Rath, T. C. Daniel, and V. Raboy, 1998. Effect of dietary phytase and high available phosphorus corn on broiler chicken performance. Poult. Sci. 77:1899-1904.

Jang, D. A., J. G. Fadel, K. C. Klasing, A. J. Mireles, Jr., R. A. Ernst, K. A. Young, A. Cook, and V. Raboy, 2003. Evaluation of low-phytate corn and barley on broiler chick performance. Poult. Sci. 82:1914-1924.

Maenz, D. D. and H. L. Classen, 1998. Phytase activity in the small intestinal brush border membrane of the chicken. Poult. Sci. 77:557-563.

National Research Council, 1994. Nutrient requirements of poultry. 9th rev. ed. National Academy Press, Washington, DC.

Nelson, T. S., L. W. Ferrara, and N. L. Storer, 1968. Phytate phosphorus content of feed ingredients derived from plants. Poult. Sci. 47:1372.

Nelson, T. S., T. R. Shieh, R. J. Wodzinski, and J. H. Hare, 1971. Effect of supplemental phytase on the utilization of phytate phosphorus by chicks. J. Nutr. 101:1289.

Nigg, B. M., and S. K. Grimstone, 1994. Bone. Pages 48-78 *in*: Biomechanics of Musculoskeletal System. B. M. Nigg and W. Herzog, ed. John Wiley & Sons, New York, NY.

Penn, C. J., G. L. Mullins, L. W. Zelazny, J. G. Warren, and J. M. McGrath, 2004. Surface runoff losses of phosphorus from Virginia soils amended with turkey manure using phytase and high available phosphorus corn diets. J. Environ. Qual. 33:1431-1439.

Potter, L. M., 1990. Phosphorus requirements for turkeys. in: Proc. 1989 Texasgulf Nutr. Symposium, Raleigh, NC. pp. 1-12.

Powers, W. J., E. R. Fritz, W. Fehr, and R. Angel, 2006. Total and water-soluble phosphorus excretion from swine fed low-phytate soybeans. J. Anim. Sci. 84:1907-1915.

Qian, H., H. P. Veit, E. T. Kornegay, V. Ravindran, and D. M. Denbow, 1996. Effects of supplemental phytase and phosphorus on histological and other tibial bone characteristics and performances of broilers fed semi-purified diets. Poult. Sci. 75:618-626.

Raboy, V., K. A. Young, J. A. Dorsch, and A. Cook, 2001. Genetics and breeding of seed phosphorus and phytic acid. J. Plant Physiol. 158:489-497.

Raboy, V., 2002. Progress in breeding low phytate crops. J. Nutr. 132:503S-505S.

Rath, N. C., G. R. Huff, W. E. Huff, and J. M. Balog, 2000. Factors regulating bone maturity and strength in poultry. Poult. Sci. 79:1024-1032.

Ravindran, V., W. L. Bryden, and E. T. Kornegay, 1995. Phytates: Occurrence, bioavailability and implications in poultry nutrition. Poult. Avian Biol. Rev. 6:125-143.

Roberson, K. D., M. W. Klunzinger, M. F. Ledwaba, A. P. Rahn, M. W. Orth, R. M. Fulton, and B. P. Marks, 2000. Effects of dietary calcium and phosphorus regimen on growth performance, bone strength, and carcass quality and yield of Large White tom turkeys. Poult. Sci. 79(Suppl. 1):68.

Sands, J. S., D. Ragland, J. R. Wilcox, and O. Adeola, 2003. Relative bioavailability of phosphorus in low-phytate soybean meal for broiler chicks. Canadian J. Anim. Sci. 83(1):95-100.

SAS Institute, 2000. SAS Online Doc. Version 8. SAS Institute Inc., Cary, NC.

Scott, T. A., and F. Boldaji, 1997. Comparison of inert markers [chromic oxide or insoluble ash (Celite™)] for determining apparent metabolizable energy of wheat- or barley-based broiler diets with or without enzymes. Poult. Sci. 76:594-598.

Snow, J. L., M. W. Douglas, A. B. Batal, M. E. Persia, P. E. Biggs, and C. M. Parsons, 2003. Efficacy of high available phosphorus corn in laying hen diets. Poult. Sci. 82:1037-1041.

Spencer, J. D., G. L. Allee, and T. E. Sauber, 2000. Growing-finishing performance and carcass characteristics of pigs fed normal and genetically modified low-phytate corn. J. Anim. Sci. 78:1529-1536.

Thompson, K. L., T. J. Applegate, R. Angel, K. Ondracek, and P. Jaynes, 2002. Effect of phosphorus level, 25-hydroxycholecalciferol (HyD), and phytase supplementation on performance of male turkeys from 0 to 18 weeks of age. Poult. Sci. 81(Suppl. 1):13.

Turner, C. H., and D. B. Burr, 1993. Basic biomechanical measurements of bone. A tutorial. Bone 14:595-608.

Veum, T. L., D. R. Ledoux, D. w. Bollinger, V. Raboy, and A. Cook, 2002. Low-phytic acid barley improves calcium and phosphorus utilization and growth performance in growing pigs. J. Anim. Sci. 80:2663-2670.

Wilcox, J. R., G. S. Premachandra, and K. A. Young, and V. Raboy, 2000. Isolation of high seed inorganic P, low-phytate soybean mutants. Crop Sci. 40:1601-1605.

Wienhold, B. J., and P. S. Miller, 2004. Phosphorus fractionation in manure from swine fed traditional and low-phytate corn diets. J. Environ. Qual. 33:389-393.

Table 2.1. Dietary treatments[1] fed turkey poults from day of hatch to 18 days of age.

	Diets			
Ingredient (%)	SBM 115	LP SBM 115	LP SBM 100	LP SBM 85
Corn Source	43.0	43.0	43.0	43.0
Soybean Meal	41.0	41.0	41.0	41.0
Poultry Meal	8.00	8.00	8.00	8.00
Limestone	1.60	2.00	1.70	1.40
Dicalcium Phosphate	2.40	1.70	1.10	0.48
Poultry Fat	2.50	2.50	2.50	2.50
DL-Methionine	0.22	0.22	0.22	0.22
Salt	0.25	0.25	0.25	0.25
Minerals (TM-90)[2]	0.20	0.20	0.20	0.20
Vitamins (NCSU-90)[3]	0.10	0.10	0.10	0.10
Selenium Supplement[4]	0.20	0.20	0.20	0.20
Sand			0.81	1.70
Celite	1.0	1.0	1.0	1.0
Total	100	100	100	100
Calculated Analysis				
Crude Protein, %	28	28	28	28
M. E. (kcal/kg)	2828	2828	2828	2828
Calcium, %	1.5	1.5	1.3	1.1
Phosphorus (total), %	1.0	0.9	0.9	0.8
Phosphorus (available), %	0.7	0.7	0.6	0.5
Lysine, %	1.8	1.8	1.8	1.8
DL-Methionine, %	0.7	0.7	0.7	0.7
Analyzed				
Crude Protein, %	29.0	28.0	27.0	28.0
Calcium, %	1.3	2.0	1.1	0.94
Phosphorus (total), %	1.0	1.1	0.8	0.72

1 Normal Soybean Meal (SBM) + 15% Above NRC (115), Low-Phytate Soybean Meal (LP SBM) + 15% Above NRC (115), Low-Phytate Soybean Meal (LP SBM) + NRC (100), Low-Phytate Soybean Meal (LP SBM) + 15% Below NRC (85).

2 Mineral composition (in g/kg of diet): zinc sulfate, 120; manganous sulfate, 120; copper sulfate, 10; calcium iodate, 2.5; colbalt sulfate, 1.0.

3 Vitamins in amounts per kilogram of diet; vitamin A, 26,400 IU; vitamin D_3, 8,000 IU; vitamin E 132 IU; vitamin B_{12}, 79.2 µg; riboflavin 26.4.

4 Provided 0.3 mg Se per kilogram of diet.

Table 2.2. Feed conversion ratios and mean body weights (g) for turkey poults fed 4 dietary treatments[1] raised to 18 days (d) of age.

	Feed Conversion Ratio[2]			Mean Body Weights (g)[3]			
Treatment	6 d	12 d	18 d	1 d	6 d	12 d	18 d
SBM 115	1.16	1.09	1.59	52	134	304	510
LP SBM 115	1.11	1.13	1.54	53	129	280	472
LP SBM 100	1.13	1.17	1.54	53	137	292	505
LP SBM 85	1.13	1.13	1.51	53	136	296	501
SEM	0.01	0.01	0.02	0.38	2.00	5.48	7.38

[1] Normal Soybean Meal (SBM) + 15% Above NRC (115), Low-Phytate Soybean Meal (LP SBM) + 15% Above NRC (115), Low-Phytate Soybean Meal (LP SBM) + NRC (100), Low-Phytate Soybean Meal (LP SBM) + 15% Below NRC (85).

[2] SEM

[3] SEM

Table 2.3. Toe ash (%), tibia ash (%), tibia phosphorus (%) and total fecal phosphorus (%) measured of turkey poults 18 days of age fed 4 dietary treatments[1].

Treatment	Toe Ash[2] (%)	Tibia Ash[3] (%)	Tibia P[4] (%)	Total Fecal P[5] (%)
SBM 115	16.76	35.19	4.8	1.3[a]
LP SBM 115	16.26	34.69	5.1	1.2[b]
LP SBM 100	16.71	34.48	4.9	1.0[c]
LP SBM 85	16.95	33.47	4.2	0.8[d]
P-value				< 0.0001
SEM	0.77	1.65	0.83	0.03

[1] Normal Soybean Meal (SBM) + 15% Above NRC (115), Low-Phytate Soybean Meal (LP SBM) + 15% Above NRC (115), Low-Phytate Soybean Meal (LP SBM) + NRC (100), Low-Phytate Soybean Meal (LP SBM) + 15% Below NRC (85).

[2] SEM

[3] SEM

[4] SEM

[5] SEM

[a-d] Means with different superscripts are significantly different ($P \leq 0.05$).

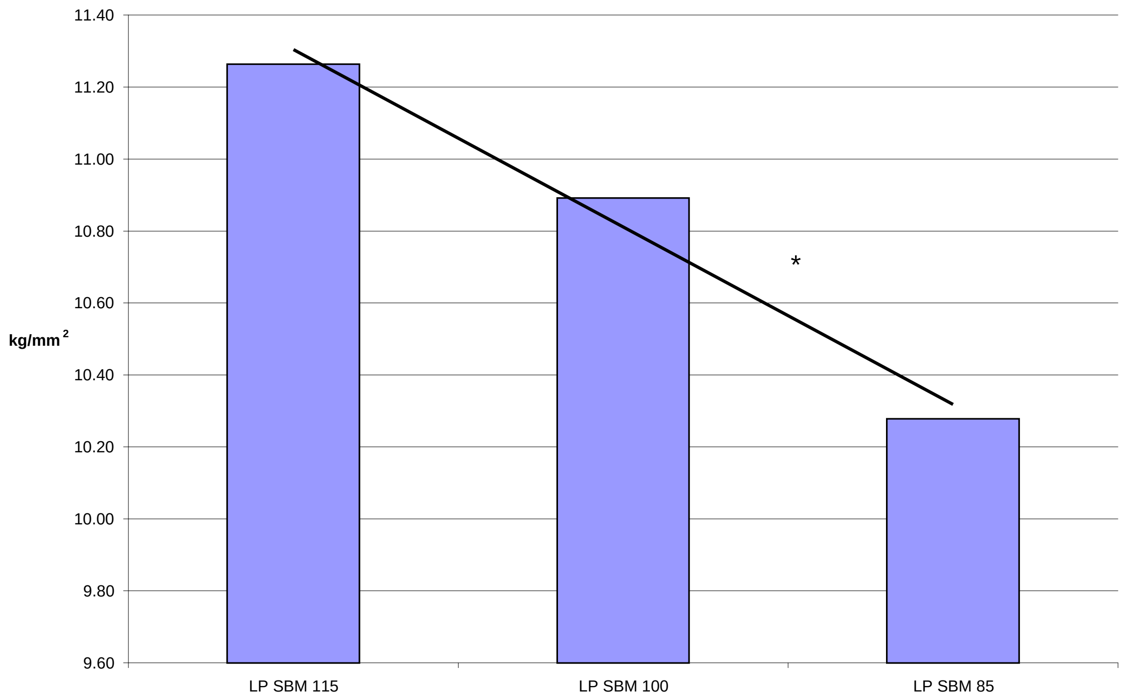


Figure 2.1. Tibia breaking strength (kg/mm^2) of poults 18 days of age fed dietary treatments[1] containing low phytate (LP)[2] soybean meal (SBM).

[1] Normal Soybean Meal (SBM) + 15% Above NRC (115), Low-Phytate Soybean Meal (LP SBM) + 15% Above NRC (115), Low-Phytate Soybean Meal (LP SBM) + NRC (100), Low-Phytate Soybean Meal (LP SBM) + 15% Below NRC (85).

[2] Poult tibia breaking strength decreased linearly as NRC recommended Ca and P levels decreased from 115 to 85% in LP SBM diets.

[3] SEM = 0.48

[*] SBM 115 (10.74 kg/mm^2) was not used in the regression analysis; however it was provided here as comparison.

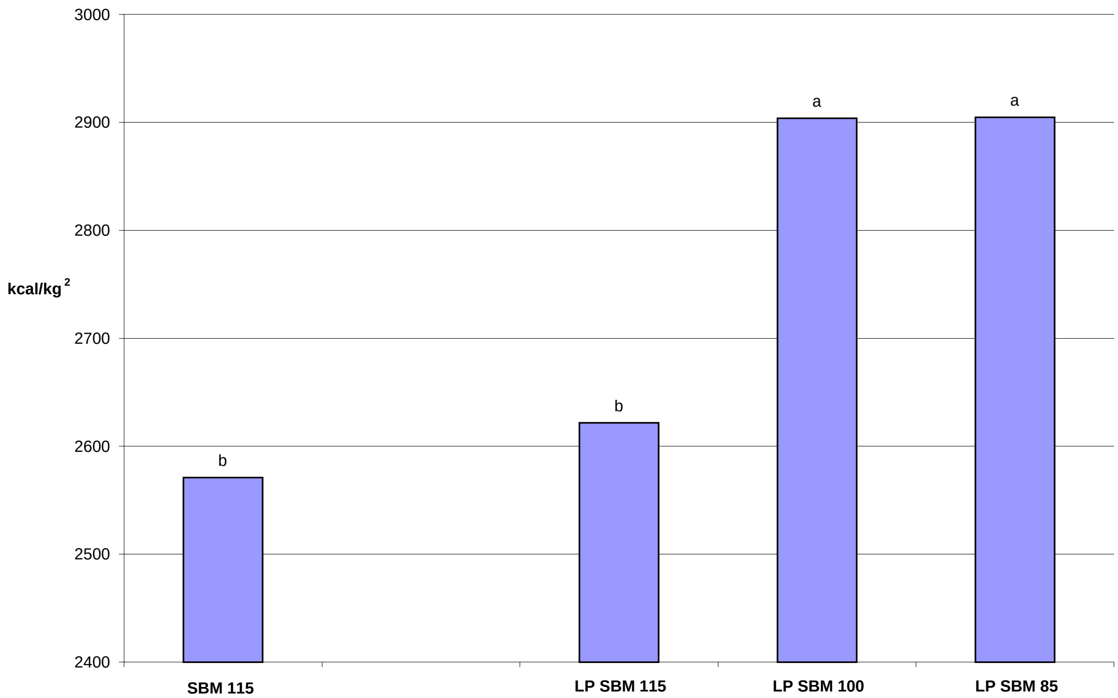


Figure 2.2. AMEn (kcal/kg) of dietary treatments[1] containing low phytate (LP) soybean meal (SBM) and normal SBM fed to poults to 18 days of age.

[1] Normal Soybean Meal (SBM) + 15% Above NRC (115), Low-Phytate Soybean Meal (LP SBM) + 15% Above NRC (115), Low-Phytate Soybean Meal (LP SBM) + NRC (100), Low-Phytate Soybean Meal (LP SBM) + 15% Below NRC (85).

[2] SEM =92.26

[a, b] Means with different superscripts are significantly different ($P \leq 0.05$).

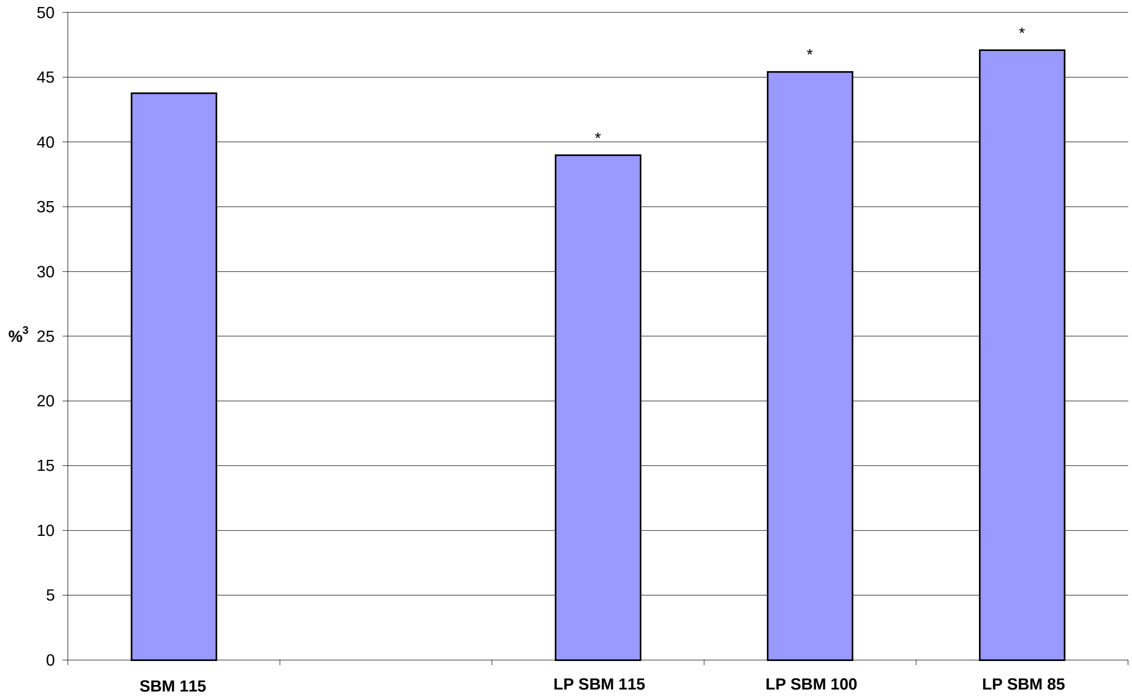


Figure 2.3. ANR (%) for poults at 18 days of age fed dietary treatments[1] containing low phytate (LP) soybean meal (SBM) and normal SBM[2].

[1] Normal Soybean Meal (SBM) + 15% Above NRC (115), Low-phytate Soybean Meal (LP SBM) + 15% Above NRC (115), Low-phytate Soybean Meal (LP SBM) + NRC (100), Low-phytate Soybean Meal (LP SBM) + 15% Below NRC (85).

[2] SBM 115 (43.8%) was not used in the regression analysis; however, it was provided here as comparison.

[3] SEM = 2.47

[*] ANR increased linearly within diets containing LP SBM as NRC recommended Ca and P levels decreased from 115 to 85% ($P \leq 0.04$; $y = -0.27 (x) + 66.6$).

MANUSCRIPT III. THE USE OF DEGERMED-DEULLED CORN AND LOW-PHYTATE SOYBEAN MEAL TO REDUCE PHOSPHORUS EXCRETION FROM POULTS RAISED TO 18 DAYS OF AGE.

ABSTRACT

An experiment was conducted to determine if feeding mechanically degermed-dehulled corn (DDC) and genetically selected low-phytate soybean meal (LP SBM) to turkey poults would support growth performance similar to diets containing normal corn (NC) and normal soybean meal (SBM) as well as reducing phosphorus (P) excretion from poults raised to 18 days (d) of age. Three hundred and thirty-six Nicholas Large White male turkey poults were housed at day of hatch in Petersime batteries with 48 pens (seven birds per pen). There were six treatments with eight pens per treatment. Poults were fed a starter ration with treatments as follows: 1) NC and SBM plus calcium (Ca) and P at 15% above recommended NRC levels (NC SBM 115), 2) NC and SBM plus Ca and P at recommended NRC levels (NC SBM 100), 3) NC and SBM plus Ca and P at 15% below recommended NRC levels (NC SBM 85), 4) DDC and LP SBM plus Ca and P at 15% above recommended NRC levels (DDC LP SBM 115), 5) DDC and LP SBM plus Ca and P at recommended NRC levels (DDC LP SBM 100), 6) DDC and LP SBM plus Ca and P at 15% below recommended NRC levels (DDC LP SBM 85). Feed and water were provided *ad libitium*. Feed consumption, by pen, calculated feed conversion ratio (FCR), and individual BW where determined at 6, 12 and 18 d. The following parameters were also measured at 18 d: percent toe and tibia ash, tibia breaking strength, apparent metabolizable energy (AMEn), apparent nitrogen

retention (ANR), and P levels in tibia and fecal samples. Means for BW, FCR, cumulative FCR, toe ash, tibia ash, nor AMEn were not significantly affected by treatment. The ANR was significantly higher when poults were fed NC and SBM. Tibia breaking strength was significantly higher when NRC Ca and P levels were at 100% and 115% of NRC recommended Ca and P levels. Fecal P was significantly lower when birds were fed DDC and LP SBM compared to NC and SBM. Fecal P was also decreased further when Ca and P decreased from 115% to 85% of recommended levels of NRC regardless of ingredient source. Using DDC and LP SBM resulted in poult performance equal to using normal corn and SBM and also resulted in reduced fecal P.

INTRODUCTION

Corn and soybean meal are commonly used primary ingredients in poultry diets are low in available P (NRC, 1994). A considerable amount of the P in these ingredients is in an organically bound storage form known as phytate P is poorly digested by poultry. Poultry lack or are limited in phosphytase, the enzyme necessary for phytate breakdown and release of stored phosphorus for absorption (Maenz and Classen, 1998). Therefore, diets are typically supplemented with inorganic P to meet the nutritional requirements of the bird. However, inclusion of P in excess of the bird's requirement may lead to the accumulation of P in the environment and subsequent eutrophication of surface waters (Honeyman, 1993). In response to environmental concerns, the poultry industry is investigating the development of new production methods that maintain performance and health while addressing the increasing environment concerns.

Presumably formulating balanced diets to maximize available P through the inclusion of dietary phytase, or using genetically altered feed ingredients would reduce organically bound P and reduce excess P excretion. The use of added phytase in monogastric diets can decrease the total P excretion by as much as 50% (Simons et al., 1990) depending on factors such as total P in the diet, the level of phytase added to the diet, and the ratio of Ca to P in the diet (Kornegay, 1996). However, some phytases are heat sensitive and activity may be lost when the feed is pelleted. Therefore, alternative methods such as using mechanically and genetically altered cereals and legumes may be considered.

Typical poultry diets consist of corn and SBM to provide adequate nutrition to support growth. In corn, approximately 90% of phytate P is located within the germ portion of the seed (O'Dell et al., 1972). Degermed-dehulled corn (DDC) is a mechanically altered corn product that provides lower phytate P levels and higher energy content as well as lower fiber content. The ability to remove the germ from the kernel through dry milling decreases the total phosphorus content of the grain from 0.30% to 0.06% P. Soybean meal (SBM) is commonly added to poultry diets as a source of protein and amino acids. However, P presents a confounding situation as 55% to 60% of the total P found in soybeans is bound to phytate (Eeckhout and Paepe, 1994; Ravindran et al., 1995).

Another approach to reduce the environmental impact of P is the use of genetically modified feedstuffs that contain reduced levels of phytate P. These varieties have been shown to possess more available P (aP) compared to conventional varieties (Wilcox et al., 2000; Raboy et al., 2001; Raboy, 2002). The relative bioavailability of P from low-phytate SBM was 15% to 25% higher compared to conventional SBM when fed to broiler chickens (Sands et al., 2003), and total P excretion decreased when feeding low-phytate SBM to swine (Powers et al., 2006). The objective of this study was to determine the effect of feeding DDC and LP SBM with varying NRC levels of Ca and P on turkey poult performance and fecal P excretion.

MATERIALS AND METHODS

One-day old Nicholas Large White (Aviagen Turkeys, Lewisburg, WV) male poults were obtained from a commercial hatchery (Sleepy Creek Hatchery, Goldsboro, NC) and randomly assigned to cages. All birds were housed in Petersime battery cage units within a climate-controlled animal room during the 18 d study period. Dietary treatments were randomly assigned to two pens in each block and the pen served as the experimental unit. There were seven birds per pen at day of hatch with eight pens per treatment. Poults were fed a starter ration with treatments as follows: 1) NC and SBM plus Ca and P at 15% above recommended NRC levels (NC SBM 115), 2) NC and SBM plus Ca and P at recommended NRC levels (NC SBM 100), 3) NC and SBM plus Ca and P at 15% below recommended NRC levels (NC SBM 85), 4) DDC and LP SBM plus Ca and P at 15% above recommended NRC levels (DDC LP SBM 115), 5) DDC and LP SBM plus Ca and P at recommended NRC levels (DDC LP SBM 100), 6) DDC and LP SBM plus Ca and P at 15% below recommended NRC levels (DDC LP SBM 85). Diets were analyzed by an independent laboratory to determine crude protein, Ca, and total P of formulated diets on an as fed basis (Table 3.1). Poults received feed and water *ad libitium*. Feed consumption, by pen, individual BW, and calculated feed conversion (FCR) were recorded at 6 day intervals beginning at day one until 18 d. On the final day of the study two birds per pen were necropsied to collect both tibias. The right tibia was used to determine breaking strength. Physical bone characteristics were determined by the three-point bending test. The load and the stress at failure, the strain and the Young's modulus (modulus of elasticity) were determined using a three-point flexural bending with a total distance of 40 mm between the two supporting ends. The load is defined as force in kilograms per square millimeter of cross-sectional area and represents bone strength. The modulus measures the stiffness of the bone as it relates to stress and strain (Rath et al., 1999). Stress is the internal resistance to deformity and strain represents the percentage of deformity (Einhorn, 1996). The rate of loading was kept constant at 10 mm/min. The middle, right toe was taken to determine percent toe ash. The left tibia was stripped of all soft tissue, fat extracted, oven dried for 24 h at 100°C and then ashed in a muffle furnace at 600°C for 24 h to determine tibia ash, expressed as percent of dry weight. Ashed samples were then assayed in order to determine percent P. Fecal samples were collected over a three-day period from each treatment to determine total fecal P, AMEn and ANR. An inert digestible marker, Celite™ (Celite Corp., Lompar, CA), was used to estimate the digestibility of dietary nutrients (Scott and Boldaji, 1997). A phosphorus microtiter assay (Appendix I) was used to determine the P concentration of tibia and fecal (total P) samples.

Data were analyzed using GLM for treatment effect and linear regression analysis within NRC levels. Differences among treatment means were partitioned using the least square means procedure of SAS (SAS Institute, Inc., 2000). Statements of significance are based on $P \leq 0.05$ unless otherwise stated.

RESULTS AND DISCUSSION

Body weight gain and FCR were not significantly affected by ingredient source, recommended NRC Ca and P levels or the interaction of ingredient source and NRC level (Table 3.2). These findings are consistent with other research where the use of high available P corn was fed to poultry (Huff et al., 1998; Snow et al., 2003) and low-phytate corn, barley, and soybeans were fed to swine (Powers et al., 2006; Spencer et al., 2000). The effect of feeding DDC as the major grain source in nursery pig diets had no effect on average daily gain. Those fed DDC tended to consume less feed than those fed normal corn which resulted in a 4% improvement in feed conversion ratio (Moeser, et al., 2002).

There were no significant treatment effects observed for toe ash, percent tibia ash, or tibia P (Table 3.3). Tibia breaking strength was not significantly affected by corn or SBM meal type; however, there was a significant linear decrease in poult tibia breaking strength as recommended NRC Ca and P levels decreased from 115% to 85% within NC and SBM treatments (Table 3.3). This agrees with Roberson et al., (2000) and Thompson et al., (2002), who reported impaired bone mineralization when birds were fed 75% to 83% of NRC recommended non-phytate P (nPP) levels, respectively, which is lower than the nPP level used in the current study. In contrast, Potter (1990) reported that the aP requirement for optimum bone mineralization of the young turkey was 0.41%. Similarly, Atia et al., (2000) fed nPP at 73% of NRC P with 100% NRC Ca and reported bone ash, strength, and density were similar to those of birds fed the control diet of 110% NRC Ca and nPP. However, when feeding nPP at 52% of NRC P and 90% of NRC Ca, bone ash, density and strength measurements were substantially lower.

The AMEn was not significantly affected by ingredient source, NRC recommended Ca and P level or the interaction of ingredient source and Ca and P level (Table 3.4). The ANR was significantly higher when poults were fed NC and SBM versus DDC and LP SBM at 18 d (Table 3.4). Fecal P was significantly lower when turkeys were fed diets containing DDC and LP SBM versus NC and SBM (Table 3.4). In addition, fecal P decreased regardless of grain source as Ca and P levels decreased from 115% to 85% of recommended NRC levels (Table 3.4). in other studies, P excretion was decreased by 48% when diets with low phytate ingredients were fed to growing pigs, and available P improved in diets containing LP SBM, resulting in reduced P excretion from pigs (Xavier et al., 2003; Powers et al., 2006). The P in low phytate corn is approximately 5 to 6 times more available than normal corn and can significantly reduce the amount of P excreted in swine waste (Spencer et al., 2000). In conclusion, feeding DDC and LP SBM resulted in poult performance equal to NC and SBM and reduced fecal P.

REFERENCES

AOAC. 1990. Official Methods of Analysis. 15th ed. Association of Official Analytical Chemists. Arlington, VA.

Atia, F. A., P. E. Waibel, I. Hermes, C. W. Carlson, and M. M. Walser, 2000. Effect of dietary phosphorus, calcium, and phytase on performance of growing turkeys. Poult. Sci. 79:231-239.

Eeckhout, W. and M. De Paepe, 1994. Total phosphorus, phytate-phosphorus and phytase activity in plant feedstuffs. Animal Feed Science and Technology 47:19-29.

Einhorn, T. A., 1996. Biomechanics of bone. In: Principles of Bone Biology, J. P. Bilezikian, L. G. Raisz, and G. A. Rodan, ed. Academic Press, San Diego. CA.

Honeyman, M. S., 1993. Environment-friendly swine feed formulation to reduce nitrogen and phosphorus excretion. Am. J. Alternative Agr. 8:128-132.

Huff, W. E., P. A. Moore Jr., P. W. Waldroup, A. L. Waldroup, J. M. Balog, G. R. Huff, N. C. Rath, T. C. Daniel, and V. Raboy, 1998. Effect of dietary phytase and high available phosphorus corn on broiler chicken performance. Poult. Sci. 77:1899-1904.

Kornegay, E. T., Z. Yi, V. Ravindran, and D. M. Denbow, 1996. Improving phytate phosphorus availability in corn and soybean meal for broilers using microbial phytase and calculation of phosphorus equivalency values for phytase. Poult. Sci. 75:240-249.

Maenz, D. D. and H. L. Classen, 1998. Phytase activity in the small intestinal brush border membrane of the chicken. Poult. Sci. 77:557-563.

Moeser, A. J., I. B. Kim, E. van Heugten, and T. Van Kempen, 2002. The nutritional value of degermed, dehulled corn for pigs and its impact on the gastrointestinal tract and nutrient excretion. J. Anim. Sci. 80:2629-2638.

National Research Council, 1988. Nutrient requirements for poultry. 8th rev. ed. National Academy Press, Washington, DC.

National Research Council, 1994. Nutrient requirements of poultry. 9th rev.ed. National Academy Press, Washington, DC.

O'Dell, B. L., A. R. de Boland, and S. R. Koirtyohann, 1972. Distribution of phytate and nutritionally important elements among the morphological components of cereal grains. J of Agri. Food Chemistry, 20:718-721.

Potter, L. M., 1990. Phosphorus requirements for turkeys. in: Proc. 1989 Texasgulf Nutr. Symposium, Raleigh, NC. pp. 1-12.

Powers, W. J., E. R. Fritz, W. Fehr, and R. Angel, 2006. Total and water-soluble phosphorus excretion from swine fed low-phytate soybeans. J. Anim. Sci. 84:1907-1915.

Raboy, V., K. A. Young, J. A. Dorsch, and A. Cook, 2001. Genetics and breeding of seed phosphorus and phytic acid. J. Plant Physiol. 158:489-497.

Raboy, V., 2002. Progress in breeding low phytate crops. J. Nutr. 132:503S-505S.

Rath, N. C., J. M. Balog, W. E. Huff, G. R. Huff, G. B. Kulkarni, and J. F. Tierce, 1999. Comparative differences in the composition and biomechanical properties of tibiae of seven- and seventy-two-week-old male and female broiler breeder chickens. Poult. Sci. 78:1232-1239.

Ravindran, V., W. L. Bryden, and E. T. Kornegay, 1995. Phytates: Occurrence, bioavailability and implications in poultry nutrition. Poult. Avian Biol. Rev. 6:125-143.

Roberson, K. D., M. W. Klunzinger, M. F. Ledwaba, A. P. Rahn, M. W. Orth, R. M. Fulton, and B. P. Marks, 2000. Effects of dietary calcium and phosphorus regimen on growth performance, bone strength, and carcass quality and yield of Large White tom turkeys. Poult. Sci. 79(Suppl. 1):68.

Sands, J. S., D. Ragland, J. R. Wilcox, and O. Adeola, 2003. Relative bioavailability of phosphorus in low-phytate soybean meal for broiler chicks. Canadian J. Anim. Sci. 83(1):95-100.

SAS Institute, 2000. SAS Online Doc. Version 8. SAS Institute Inc., Cary, NC.

Scott, T. A., and F. Boldaji, 1997. Comparison of inert markers [chromic oxide or insoluble ash (Celite™)] for determining apparent metabolizable energy of wheat- or barley-based broiler diets with or without enzymes. Poult. Sci. 76:594-598.

Simons, P. C. M., H. A. J. Versteegh, A. W. Jongbloed, P. A. Kemme, P. Slump, K. D. Bos, M. G. E. Wolters, R. F. Beudeker, and G. J. Verschoor, 1990. Improvement of phosphorus availability by microbial phytase in broilers and pigs. Br. J. Nutr. 64:525-540.

Snow, J. L., M. W. Douglas, A. B. Batal, M. E. Persia, P. E. Biggs, and C. M. Parsons, 2003. Efficacy of high available phosphorus corn in laying hen diets. Poult. Sci. 82:1037-1041.

Spencer, J. D., G. L. Allee, and T. E. Sauber, 2000. Growing-finishing performance and carcass characteristics of pigs fed normal and genetically modified low-phytate corn. J. Anim. Sci. 78:1529-1536.

Spencer, J. D., G. L. Allee, and T. E. Sauber, 2000. Phosphorus bioavailability and digestibility of normal and genetically modified low-phytate corn for pigs. J. Anim. Sci. 78:675-681.

Thompson, K. L., T. J. Applegate, R. Angel, K. Ondracek, and P. Jaynes, 2002. Effect of phosphorus level, 25-hydroxycholecalciferol (HyD), and phytase supplementation on performance of male turkeys from 0 to 18 weeks of age. Poult. Sci. 81(Suppl. 1):13.

Wilcox, J. R., G. S. Premachandra, and K. A. Young, and V. Raboy, 2000. Isolation of high seed inorganic P, low-phytate soybean mutants. Crop Sci. 40:1601-1605.

Xavier, E.G., G.L. Cromwell, and M.D. Lindemann. 2003. Phytase additions to conventional or low-phytate corn-soybean meal diets on phosphorus balance in growing pigs. J. Anim. Sci. 81(Suppl. 1):258.

Table 3.1. Dietary treatments[1] fed to turkey poults from day of hatch to 18 days of age.

Ingredient (%)	NC SBM 115	NC SBM 100	NC SBM 85	DDC LP SBM 115	DDC LP SBM 100	DDC LP SBM 85
Corn Source	43.0	43.0	43.0	39.3	39.3	39.3
Soybean Meal	40.5	40.6	41.0	42.0	42.0	42.0
Poultry Meal	8.00	8.0	8.0	8.0	8.0	8.0
Limestone	1.60	1.31	1.05	2.00	1.45	1.35
Dicalcium Phosphate	2.40	1.81	1.20	1.80	1.20	0.625
Poultry Fat	2.50	2.50	2.50	2.50	2.50	2.50
DL-Methionine	0.22	0.22	0.22	0.22	0.22	0.22
Salt	0.25	0.25	0.25	0.25	0.25	0.25
Minerals (TM-90)[2]	0.20	0.20	0.20	0.20	0.20	0.20
Vitamins (NCSU-90)[3]	0.10	0.10	0.10	0.10	0.10	0.10
Selenium Supplement[4]	0.20	0.20	0.20	0.20	0.20	0.20
Sand		0.81	1.70	2.60	3.70	4.40
Celite	1.00	1.00	1.00	1.00	1.00	1.00
Total	100	100	100	100	100	100
Calculated Analysis						
Crude Protein, %	28.0	28.0	28.0	28.0	28.0	28.0
M. E. (kcal/kg)	2800	2800	2800	2800	2800	2800
Calcium, %	1.5	1.3	1.1	1.5	1.2	1.1
Phosphorus (total), %	1.0	0.9	0.8	0.9	0.8	0.66
Phosphorus (available), %	0.74	0.64	0.52	0.74	0.62	0.52
Lysine, %	1.8	1.8	1.8	1.8	1.8	1.8
DL-Methionine, %	0.7	0.7	0.7	0.7	0.7	0.7
Analyzed						
Crude Protein, %	29.0	27.0	26.0	26.0	27.0	28.0
Calcium, %	1.3	1.2	1.0	2.0	1.0	0.94
Phosphorus (total), %	1.0	0.9	0.74	1.1	0.9	0.72

[1]Normal Corn (NC) and Normal Soybean Meal (SBM) + 15% Above NRC (115), NC and SBM + NRC (100), NC and SBM + 15% Below NRC (85), Degermed-Dehulled Corn (DDC) and Low-Phytate Soybean Mean (LP SBM) + 15% Above NRC (115), DDC and LP SBM + NRC (100), DDC and LP SBM + 15% Below NRC (85).

[2]Mineral composition (in g/kg of diet): zinc sulfate, 120; manganous sulfate, 120; copper sulfate, 10; calcium iodate, 2.5; colbalt sulfate, 1.0.

[3]Vitamins in amounts per kilogram of diet; vitamin A, 26,400 IU; vitamin D_3, 8,000 IU; vitamin E 132 IU; vitamin B_{12}, 79.2 µg; riboflavin 26.4.

[4]Provided 0.3 mg Se per kilogram of diet.

Table 3.2. Feed conversion ratios and mean body weights (g) for turkey poults fed 6 dietary treatments[1] raised to 18 days (d) of age.

	Feed Conversion Ratio[2]			Body Weights (g)[3]			
Treatment	6 d	12 d	18 d	1 d	6 d	12 d	18 d
NC SBM	1.1	1.7	1.4	53	142	245	385
DDC LP SBM	1.1	1.6	1.4	53	141	247	394
115	1.1	1.7	1.4	53	142	238	389
100	1.1	1.7	1.3	53	138	237	381
85	1.1	1.6	1.5	52	144	262	399
SEM	0.03	0.1	0.1	0.8	2.9	13.6	18.4

[1] Normal Corn (NC) and Normal Soybean Meal (SBM) + 15% Above NRC (115), Normal Corn (NC) and Normal Soybean Meal (SBM) + NRC (100), Normal Corn (NC) and Normal Soybean Meal (SBM) + 15% Below NRC (85), Degermed-Dehulled Corn (DDC) and Low-Phytate Soybean Mean (LP SBM) + 15% Above NRC (115), Degermed-Dehulled Corn (DDC) and Low-Phytate Soybean Mean (LP SBM) + NRC (100), Degermed-Dehulled Corn (DDC) and Low-Phytate Soybean Mean (LP SBM) + 15% Below NRC (85).

[2] SEM

[3] SEM

Table 3.3. Toe ash (%), tibia ash (%), tibia phosphorus (%), and tibia breaking strength (kg/mm^2) of turkey poults fed 6 dietary treatments[1] to 18 days of age.

Treatment	Toe Ash[2] (%)	Tibia Ash[3] (%)	Tibia P[4] (%)	Tibia Breaking Strength[5] (kg/mm^2)
NC SBM	16.4	34.8	5.8	9.7
DDC LP SBM	15.7	35.7	5.8	9.6
115	15.7	35.5	5.8	10.6[a]
100	16.2	34.5	5.7	9.8[a]
85	16.2	34.5	5.8	8.5[b]
P-value				0.02
SEM	0.8	1.2	0.2	0.8

[1] Normal Corn (NC) and Normal Soybean Meal (SBM) + 15% Above NRC (115), Normal Corn (NC) and Normal Soybean Meal (SBM) + NRC (100), Normal Corn (NC) and Normal Soybean Meal (SBM) + 15% Below NRC (85), Degermed-Dehulled Corn (DDC) and Low-Phytate Soybean Mean (LP SBM) + 15% Above NRC (115), Degermed-Dehulled Corn (DDC) and Low-Phytate Soybean Mean (LP SBM) + NRC (100), Degermed-Dehulled Corn (DDC) and Low-Phytate Soybean Mean (LP SBM) + 15% Below NRC (85).

[2] SEM

[3] SEM

[4] SEM

[5] SEM

[a, b] At 18 days of age there was a NRC effect ($P \leq 0.05$). Poults fed NRC recommended NRC Ca and P levels at 115 and 100% had a higher average body weight than poults fed 85%.

Table 3.4. AMEn (kcal/kg), ANR (%), and fecal phosphorus (%) when 6 dietary treatments[1] were fed to turkey poults to 18 days of age.

Treatment	AMEn (kcal/kg)[2]	ANR (%)[3]	Fecal P (%)[4]
NC SBM	2962	42[a]	1.7[a]
DDC LP SBM	2904	37[b]	1.4[b]
P-value		0.05	0.0007
115	2875	40	1.8[a]
100	2987	39	1.6[b]
85	2937	40	1.3[c]
P-value			<0.0001
SEM	54	2.7	0.1

[1] Normal Corn (NC) and Normal Soybean Meal (SBM) + 15% Above NRC (115), Normal Corn (NC) and Normal Soybean Meal (SBM) + NRC (100), Normal Corn (NC) and Normal Soybean Meal (SBM) + 15% Below NRC (85), Degermed-Dehulled Corn (DDC) and Low-Phytate Soybean Mean (LP SBM) + 15% Above NRC (115), Degermed-Dehulled Corn (DDC) and Low-Phytate Soybean Mean (LP SBM) + NRC (100), Degermed-Dehulled Corn (DDC) and Low-Phytate Soybean Mean (LP SBM) + 15% Below NRC (85).

[2] SEM

[3] SEM

[4] SEM

[a, b] Means within a treatment and column lacking a common superscript differ significantly ($P \leq 0.05$).

MANUSCRIPT IV. THE USE OF DEGERMED-DEHULLED CORN FOR REARING TURKEY TOMS TO MARKET AGE.

ABSTRACT

Degermed-dehulled corn (DDC) is produced through a dry milling process and results in the removal of 80% of the corn phytate phosphorus (P). An experiment was conducted to determine if feeding DDC to male turkey poults would support growth and performance as well as feeding normal corn (NC) for rearing turkeys to 18 weeks of age (wk). Five hundred and seventy-six Nicholas male turkey poults were reared in a curtain-sided house with 32 pens (18 birds per pen) until market age with 8 pens per treatment. There were four treatments as follows: 1) normal corn (NC) plus calcium (Ca) and phosphorus (P) at industry recommended levels (NC Hi), 2) NC plus Ca and P at 15% below recommended NRC levels (NC Lo), 3) DDC plus Ca and P at industry recommended levels (DDC Hi), 4) DDC plus Ca and P at 15% below recommended NRC levels (DDC Lo). Toms were fed typical starter, grower, and finisher rations. Feed and water were provided *ad libitium*. Individual body weight (BW), feed consumption (by pen) and feed conversion (FCR) were determined at 3, 6, 9, 12, and 18 wk. Percent toe ash, tibia breaking strength, apparent metabolizable energy (AMEn), apparent nitrogen retention (ANR), and fecal P levels were measured at 3 and 6 wk. Data were analyzed using the GLM and means were separated using LSMEANS of SAS ($P \leq 0.05$). Corn type had no effect on any parameter measured. Neither BW nor FCR were affected by Ca and P level at 18 wk. At 3 wk, poults fed Hi Ca and P levels vs. Lo Ca and P levels had

higher toe ash ($P \leq 0.04$; 16.6% vs. 15.1%), increased bone breaking strength ($P \leq 0.05$; 10.70 kg/mm^2 vs. 10.0 kg/mm^2) and increased fecal P ($P \leq 0.0001$; 2.4% vs. 1.4%). At 6 wk, feeding Hi Ca and P levels vs. Lo Ca and P levels resulted in increased bone breaking strength ($P \leq 0.001$; 11.98 kg/mm^2 vs. 10.25 kg/mm^2), fecal P ($P \leq 0.0002$; 3.3% vs. 1.4%), and AMEn ($P \leq 0.01$; 3058 kcal/kg vs. 2794 kcal/kg). ANR was not affected by corn type, Ca and P level or the interaction of the two at 3 or 6 wk. Using DDC resulted in turkey performance equal to using normal corn.

INTRODUCTION

Due to growing concerns about the effects of excreted phosphorus (P) on surface water eutrophication, it is becoming essential to provide levels of dietary P that sustain economical turkey performance while reducing P excretion. Phosphorus has been extensively studied as an essential nutrient in the diets of poultry. Diets are composed primarily of feed ingredients of plant origin such as corn and soybean meal to meet the nutritional needs of the bird. Plants are a source of P in the diet; however, it is present as phytate, the storage form of P in plants, (O'Dell et al., 1972; Raboy, 1997) which is relatively unavailable to monogastric animals including poultry (Van der Klis et al., 1997). Phytate storage is responsible for the low availability of P since poultry are either limited in or lack the endogenous enzyme phytase needed to hydrolyze P from the phytate molecule (Van der Klis et al., 1997). As a result, poultry diets are typically supplemented with inorganic P to meet the P requirements of the bird. The phytate P present but not utilized in the diet is excreted in the feces. The P not utilized by crops in fields were turkey liter has been applied can leach and runoff to reach surface waters causing eutrophication (Cromwell and Coffey, 1991).

The opportunity exists to reduce fecal P through dietary management. Alternative approaches to dietary management such as the incorporation of feed additives (enzymes) and the use of feed ingredients with lower levels of phytate P are available. Inclusion of phytase has a beneficial effect on P availability in poultry (Van der Klis, 1997; Simmons et al, 1990). The recent development of a corn variety with low phytate P and high available P has also resulted in reduced fecal P excretion by poultry (Waldroup et al., 2000).

Another approach to reducing dietary P levels and minimizing P in livestock excreta is the development of mechanically altered feedstuffs such as degermed-dehulled corn. Degermed-dehulled corn is a by-product produced from the dry milling of corn. Corn is comprised of the germ, hull and the endosperm. Approximately 80% of the phytate P in corn is located in the germ (Klasing, 1998). The dry milling process separates the hull and the germ from the endosperm, and removal of the germ results in the elimination of a large segment of the indigestible portion of phytate P (Applegate, 2005). It is this removal of the phytate P rich portion of the corn kernel that makes DDC an innovative alternative feedstuff for turkeys. The objective of this study was to determine the effect of feeding mechanically modified degermed-dehulled corn with two levels of Ca and P on turkey performance and fecal P excretion raised to market age.

MATERIALS AND METHODS

The design of this study was a randomized complete block design (RCB) with a 2X2 factorial arrangement of treatments. Nicholas male turkey poults (576) were reared in a curtain-sided house with 32 pens (18 birds per pen) until market age at 18 wk. The house contained four rows of 12 pens with each row of pens representing a block. Dietary treatments were randomly assigned to two pens in each block and the pen served as the experimental unit. The dietary treatments were typical corn-soy based diets meeting NRC (1994) nutrient recommendations for turkeys except for Ca and P as noted. There were two types of corn (normal dent corn and degermed-dehulled corn) and two levels of dietary Ca and P (Tables 4.1-4.6). The four dietary treatments were as follows: 1) normal corn (NC) plus calcium (Ca) and phosphorus (P) at industry recommended levels (NC Hi), 2) NC plus Ca and P at 15% below recommended NRC levels (NC Lo), 3) DDC plus Ca and P at industry recommended levels (DDC Hi), 4) DDC plus Ca and P at 15% below recommended NRC levels (DDC Lo). Diets were analyzed to determine crude protein, calcium, and total P content of formulated diets on an as fed basis (Tables 4.1-4.3). Feed and water were provided *ad libitium*. Feed consumption, by pen, feed conversion (FCR) and individual BW were determined at 3, 6, 9, 12 and 18 wk. The following parameters were also measured at 3 and

6 weeks: AMEn, ANR, percent toe ash, tibia breaking strength, and fecal P levels. At 3 and 6 wk, two birds per pen were necropsied to collect the right tibia which was used to determine breaking strength and the middle toe was taken to determine percent toe ash. Physical bone characteristics were determined by the three-point bending test. The load and the stress at failure, the strain and the Young's modulus (modulus of elasticity) were determined at 3 and 6 wk using a three-point flexural bending with a total distance of 50 mm and 70 mm, respectively, between the two supporting ends. The load is defined as force in kilograms per square millimeter of cross-sectional area and represents bone strength. The modulus measures the stiffness of the bone as it relates to stress and strain (Rath et al., 1999). Stress measures the internal resistance to deformity and strain represents the percentage of deformity (Einhorn, 1996). The rate of loading was kept constant at 30 mm/min.

Fecal samples were collected over a three-day period from each treatment to determine total fecal P, AMEn and ANR. An inert digestible marker, Celite™ (Celite Corp., Lompar, CA), was used to estimate the digestibility of dietary nutrients (Scott and Boldaji, 1997). A phosphorus microtiter assay (Appendix I) was used to determine the P concentration of diet and fecal (total P) samples.

Data were analyzed using GLM. Differences among treatment means were partitioned using the least square means procedure of SAS (SAS Institute, Inc., 2000). Statements of significance are based on $P \leq 0.05$ unless otherwise stated.

RESULTS AND DISSCUSION

Corn type had no effect on turkey performance. In addition, BW and FCR of 18 week old turkeys were not affected by Ca and P level. Similarly, Yan et al., (2003) found no significant effects on BW or FCR at any age when comparing the effects of feeding normal corn versus a high available P (aP) corn. However, turkeys fed Hi Ca and P levels had better BW gain (Table 4.7) and FCR (Table 4.8) at 9 and 12 wk. Similarly, 9 and 12 wk turkey hens (raised to 15 wk) fed 0.6% NRC levels of aP had higher BW gain and better FCR than those fed lower aP levels (0.45%) (Ledoux et al., 1995). The lack of aP level effect on 18 week performance may mean that turkey hens' Ca and P requirement for growth is lower than that listed by NRC (NRC, 1994; Ledoux et al, 1995). Similar studies examined turkey BW gain when comparing a control diet with 110% NRC Ca and non-phytate phosphorus (nPP) to a diet with 73% of NRC recommended nPP, which supports this suggestion (Atia et al., 2000). Roberson et al., (2000) reported impaired growth from 3 to 17 wk when birds were fed 75% of NRC P while noting that the inclusion of nPP above NRC recommendations provided no additional benefit to growth. Thompson et al., (2002) reported birds were substantially lighter when fed diets containing lower (83%) levels of NRC aP. However, Potter (1990) reported that the aP requirement for optimum body weight gain of the young turkey was 0.41%, which is lower than the aP used by Roberson et al., (2000); Thompson et al., (2002); Ledoux et al, (1995) or in the current study. Atia et al., (2000), utilizing lower (52%) levels of NRC recommended nPP (90% Ca) reported inferior growth performance of turkeys grown to market age. In the current study, BW was similar regardless of treatment. It is the lack of nPP level effect on performance in this study with the results reported by others that one might conclude that turkeys can be fed NRC recommended Ca and P levels or at least 15% below levels without impairing BW and FCR performance.

Toe ash, bone breaking strength, and fecal P levels are additional ways in which to measure the effects of dietary P level. At 3 and 6 wk, two birds per pen were sacrificed to determine toe ash and tibia breaking strength (Table 4.9). Toe ash has been shown to be a good measurement of P status and accurate in determining P availability for poultry (Waldroup, 1999). In the current study, neither toe ash nor tibia breaking strength was affected by corn source (Table 4.9). Feeding Lo Ca and P levels significantly decreased toe ash at 3 wk and tibia breaking strength at 6 wk compared to feeding industry recommended Ca and P levels. These results agree with Roberson et al., (2004) and Thompson et al., (2002), who reported impaired bone mineralization when birds were fed 75% to 83% of NRC recommended nPP levels, respectively, which is lower than the nPP level used in the current study. In contrast, Potter (1990) reported that the aP requirement for optimum bone mineralization of the young turkey was 0.41%. Similarly, Atia et al., (2000) fed 73% of NRC level of P with 100% NRC Ca and reported bone ash, strength, and density were similar to the control diet of 110% NRC Ca and nPP. However, when feeding nPP at 52% of NRC and 90% Ca, bone ash, density, and strength measurements were substantially lower.

At 3 and 6 wk, fecal samples were collected for three days to determine AMEn, ANR, and total fecal P (Table 4.10). There were significant decreases in fecal P at 3 and 6 wk when feeding Lo Ca and P levels. This agrees with Ledoux et al, (1995) who reported percent litter P at 15 wk was significantly decreased when turkey hens were fed lower levels of aP.

In comparing DDC as a replacement for corn when fed to turkeys raised to market age there was no consistent differences among any parameters tested. However, feeding Lo Ca and P levels versus Hi Ca and P levels had decreased toe ash, tibia breaking strength and fecal P. In conclusion, feeding DDC to commercial turkeys to 18 weeks of age resulted in performance equal to feeding normal corn. Reducing Ca and P levels 15% below recommended NRC levels can reduce fecal P without impairing body weight and feed conversion but may have negative effects on bone growth.

REFERENCES

Applegate, T. J., 2005. The nutritional value of dehulled-degermed corn for broiler chickens and its impact on nutrient excretion. Poult. Sci. 84:742-747.

Atia, F. A., P. E. Waibel, I. Hermes, C. W. Carlson, and M. M. Walser, 2000. Effect of dietary phosphorus, calcium, and phytase on performance of growing turkeys. Poult. Sci. 79:231-239.

Cromwell, G. L., and R. D. Coffey, 1991. Phosphorus - A key essential nutrient, yet a possible major pollutant – Its central role in animal nutrition. Pages 133-145 in: Biotechnology in the Feed Industry. T. P. Lyons ed. Alltech Publications, Nicholasville, KY.

Einhorn, T. A., 1996. Biomechanics of bone. In: Principles of Bone Biology, J. P. Bilezikian, L. G. Raisz, and G. A. Rodan, ed. Academic Press, San Diego. CA.

Klasing, K. C., 1998. Minerals. in: Comparative Avian Nutrition. CAB International, New York, NY. pp 234-276.

Ledoux, D. R., K. Zyla, and T. L. Veum, 1995. Substitution of phytase for inorganic phosphorus for turkey hens. J. Appl. Poultry Res. 4:157-163.

National Research Council, 1994. Nutrient requirements of poultry. 9th rev. ed. National Academy Press, Washington, DC.

O'Dell, B. L., A. deBoland, and R. Koirtyohann, 1972. Distribution of phytate and nutritionally important elements among the morphological components of cereal grains. J. Agric. Food Chem., 20, 718.

Potter, L. M., 1990. Phosphorus requirements for turkeys. Pages 1-12 in: Proc. 1989 Texasgulf Nutr. Symposium, Raleigh, NC.

Raboy, V., 1997. Accumulation and storage of phosphate and minerals. In: Advances in cellular and molecular biology of plants. Vo. 4. Cellular and molecular biology of plant seed development. B. A. Larkins and I. K. Vasil, ed. Kluwer Publishers, Dordrecht, The Netherlands.

Rath, N. C., J. M. Balog, W. E. Huff, G. R. Huff, G. B. Kulkarni, and J. F. Tierce, 1999. Comparative differences in the composition and biomechanical properties of tibiae of seven- and seventy-two-week-old male and female broiler breeder chickens. Poult. Sci. 78:1232-1239.

Roberson, K. D., M. W. Klunzinger, M. F. Ledwaba, A. P. Rahn, M. W. Orth, R. M. Fulton, and B. P. Marks, 2000. Effects of dietary calcium and phosphorus regimen on growth performance, bone strength, and carcass quality and yield of Large White tom turkeys. Poult. Sci. 79(Suppl. 1):68.

Roberson, K. D. M. W. Klunzinger, and R. A. Charbeneau 2004. Benefit of feeding dietary calcium and nonphytate phosphorus levels above National Research Council recommendations to tom turkeys in the growing-finishing phases. Poultry Sci. 83:689-695.

SAS Institute, 2000. SAS Online Doc. Version 8. SAS Institute Inc., Cary, NC.

Scott, T. A., and F. Boldaji, 1997. Comparison of inert markers [chromic oxide or insoluble ash (Celite™)] for determining apparent metabolizable energy of wheat- or barley-based broiler diets with or without enzymes. Poult. Sci. 76:594-598.

Simons, P. C. M., H. A. J. Versteegh, A. W. Jongbloed, P. A. Kemme, P. Slump, K. D. Bos, M. G. E. Wolters, R. F. Beudeker, and G. J. Verschoor, 1990. Improvement of phosphorus availability by microbial phytase in broilers and pigs. Br. J. Nutr. 64:525-540.

Thompson, K. L., T. J. Applegate, R. Angel, K. Ondracek, and P. Jaynes, 2002. Effect of phosphorus level, 25-hydroxycholecalciferol (HyD), and phytase supplementation on performance of male turkeys from 0 to 18 weeks of age. Poult. Sci. 81(Suppl. 1):13.

Van der Klis, J. D., H. A. J. Versteegh, P. C. M. Simons, and A. K. Kies, 1997. The efficacy of phytase in corn-soybean meal-based diets for laying hens. Poult. Sci. 76:1535-1542.

Waldroup, P. W., 1999. Nutritional approached to reducing phosphorus excretion by poultry. Poultry Sci. 78:683-691.

Waldroup, P. W., J. H. Kersey, E. A. Saleh, C. A. Fritts, F. Yan, . L. Stillborn, R. C. Crum, Jr., and V. Raboy, 2000. Nonphytate phosphorus requirement and phosphorus excretion of broiler chicks fed diets composed of normal or high available phosphate corn with and without microbial phytase. Poult. Sci., 79:1451-1459.

Yan, F., C, A, Fritts, P. W. Waldroup, H. L. Stillborn, D. Rice, R. C. Crum, Jr. and V. Raboy, 2003. Comparison of normal and high available phosphorus corn with and without phytase supplementation in diets for male large white turkeys grown to market weights. International Journal of Poultry Science 2 (2): 83-90.

Table 4.1. Dietary treatments[1] fed to male turkeys from day of hatch to 3 weeks of age.

Ingredient (%)	Diets			
	NC Hi	NC Lo	DDC Hi	DDC Lo
Corn Source	42.2	42.8	40.8	40.8
Soybean Meal	40.6	40.6	40.6	40.6
Poultry Meal	8.0	8.0	8.0	8.0
Limestone	1.2	1.2	1.0	1.0
Dicalcium Phosphate	2.8	1.4	3.0	1.6
Poultry Fat	2.6	2.6	2.6	2.6
DL-Methionine	0.26	0.26	0.26	0.26
Salt	0.36	0.36	0.36	0.36
Minerals (TM-90)[2]	0.20	0.20	0.20	0.20
Vitamins (NCSU-90)[3]	0.20	0.20	0.20	0.20
Selenium Supplement[4]	0.08	0.08	0.08	0.08
Sand		0.8	1.4	2.8
Celite	1.00	1.00	1.00	1.00
Total	100	100	100	100
Calculated Analysis				
Crude Protein, %	28.0	28.0	28.0	28.0
M. E. (kcal/kg)	2,800	2,800	2,800	2,800
Calcium, %	1.35	1.02	1.35	1.02
Phosphorus (total), %	1.10	0.80	0.90	0.66
Phosphorus (available), %	0.78	0.51	0.78	0.51
Lysine, %	1.8	1.8	1.8	1.8
DL-Methionine, %	0.7	0.7	0.7	0.7
Analyzed				
Crude Protein, %	29.8	28.4	26.3	27.5
Calcium, %	1.52	1.22	1.69	1.27
Phosphorus (total), %	1.15	0.87	1.14	0.72

[1] Normal Corn (NC) + Industry Ca and P (Hi), Normal Corn (NC) + 15% Below NRC (Lo), Degermed-Dehulled Corn (DDC) + Industry Ca and P (Hi), Degermed-Dehulled Corn (DDC) + 15% Below NRC (Lo).

[2] Mineral composition (in g/kg of diet): zinc sulfate, 120; manganous sulfate, 120; copper sulfate, 10; calcium iodate, 2.5; cobalt sulfate, 1.0.

[3] Vitamins in amounts per kilogram of diet; vitamin A, 26,400 IU; vitamin D3, 8,000 IU; Vitamin E, 132 IU; Vitamin B12, 79.2 µg; riboflavin 26.4.

[4] Provided 0.3 mg Se per kilogram of diet.

Table 4.2. Dietary treatments[1] fed to male turkeys from 3-6 weeks of age.

	Diets			
Ingredient (%)	NC Hi	NC Lo	DDC Hi	DDC Lo
Corn Source	45.1	45.1	45.9	45.9
Soybean Meal	37.7	37.7	38.0	38.0
Poultry Meal	6.0	6.0	6.0	6.0
Limestone	1.1	0.95	1.05	0.8
Dicalcium Phosphate	2.8	1.1	2.9	1.3
Poultry Fat	4.8	4.8	3.5	3.5
DL-Methionine	0.21	0.21	0.21	0.21
Salt	0.38	0.38	0.38	0.38
Minerals (TM-90)[2]	0.20	0.20	0.20	0.20
Vitamins (NCSU-90)[3]	0.20	0.20	0.20	0.20
Selenium Supplement[4]	0.04	0.04	0.04	0.04
Sand		1.80		1.90
Celite	1.00	1.00	1.00	1.00
Total	100	100	100	100
Calculated Analysis				
Crude Protein, %	26.0	26.0	26.0	26.0
M. E. (kcal/kg)	2,900	2,900	2,900	2,900
Calcium, %	1.30	0.85	1.30	0.85
Phosphorus (total), %	1.04	0.73	1.00	0.68
Phosphorus (available), %	0.74	0.43	0.74	0.43
Lysine, %	1.6	1.6	1.6	1.6
DL-Methionine, %	0.6	0.6	0.6	0.6
Analyzed				
Crude Protein, %	26.2	26.5	25.9	24.4
Calcium, %	1.38	1.02	1.22	0.94
Phosphorus (total), %	1.03	0.74	1.07	0.72

[1] Normal Corn (NC) + Industry Ca and P (Hi), Normal Corn (NC) + 15% Below NRC (Lo), Degermed-Dehulled Corn (DDC) + Industry Ca and P (Hi), Degermed-Dehulled Corn (DDC) + 15% Below NRC (Lo).

[2] Mineral composition (in g/kg of diet): zinc sulfate, 120; manganous sulfate, 120; copper sulfate, 10; calcium iodate, 2.5; cobalt sulfate, 1.0.

[3] Vitamins in amounts per kilogram of diet; vitamin A, 26,400 IU; vitamin D3, 8,000 IU; Vitamin E, 132 IU; Vitamin B12, 79.2 µg; riboflavin 26.4.

[4] Provided 0.3 mg Se per kilogram of diet.

Table 4.3. Dietary treatments[1] fed to male turkeys from 6-9 weeks of age.

	Diets			
Ingredient (%)	NC Hi	NC Lo	DDC Hi	DDC Lo
Corn Source	49.8	49.8	49.7	49.7
Soybean Meal	35.5	35.5	36.5	36.5
Poultry Meal	3.0	3.0	3.0	3.0
Limestone	1.10	0.88	1.0	0.78
Dicalcium Phosphate	2.8	1.0	2.9	1.2
Poultry Fat	6.5	6.5	5.5	5.5
DL-Methionine	0.22	0.22	0.22	0.22
Salt	0.40	0.40	0.40	0.40
Minerals (TM-90)[2]	0.20	0.20	0.20	0.20
Vitamins (NCSU-90)[3]	0.20	0.20	0.20	0.20
Selenium Supplement[4]	0.04	0.04	0.04	0.04
Sand				
Celite				
Total	100	100	100	100
Calculated Analysis				
Crude Protein, %	24.0	24.0	24.0	24.0
M. E. (kcal/kg)	3,000	3,000	3,000	3,000
Calcium, %	1.20	0.72	1.20	0.72
Phosphorus (total), %	0.95	0.80	0.90	0.70
Phosphorus (available), %	0.69	0.36	0.69	0.36
Lysine, %	1.5	1.5	1.5	1.5
DL-Methionine, %	0.5	0.5	0.5	0.5
Analyzed				
Crude Protein, %	23.9	25.2	22.0	24.4
Calcium, %	1.22	0.89	1.45	0.77
Phosphorus (total), %	0.95	0.64	0.95	0.60

[1] Normal Corn (NC) + Industry Ca and P (Hi), Normal Corn (NC) + 15% Below NRC (Lo), Degermed-Dehulled Corn (DDC) + Industry Ca and P (Hi), Degermed-Dehulled Corn (DDC) + 15% Below NRC (Lo).

[2] Mineral composition (in g/kg of diet): zinc sulfate, 120; manganous sulfate, 120; copper sulfate, 10; calcium iodate, 2.5; cobalt sulfate, 1.0.

[3] Vitamins in amounts per kilogram of diet; vitamin A, 26,400 IU; vitamin D3, 8,000 IU; Vitamin E, 132 IU; Vitamin B12, 79.2 µg; riboflavin 26.4.

[4] Provided 0.3 mg Se per kilogram of diet.

Table 4.4. Dietary treatments[1] fed to male turkeys from 9-12 weeks of age.

	Diets			
Ingredient (%)	NC Hi	NC Lo	DDC Hi	DDC Lo
Corn Source	52.6	52.6	52.4	52.5
Soybean Meal	33.8	33.8	35.0	35.0
Poultry Meal				
Limestone	1.15	0.88	1.05	0.75
Dicalcium Phosphate	2.9	1.08	3.10	1.30
Poultry Fat	8.2	8.2	7.0	7.0
DL-Methionine	0.20	0.20	0.21	0.21
Salt	0.43	0.43	0.45	0.45
Minerals (TM-90)[2]	0.20	0.20	0.20	0.20
Vitamins (NCSU-90)[3]	0.20	0.20	0.20	0.20
Selenium Supplement[4]	0.04	0.04	0.04	0.04
Sand				
Celite				
Total	100	100	100	100
Calculated Analysis				
Crude Protein, %	22.0	22.0	22.0	22.0
M. E. (kcal/kg)	3,100	3,100	3,100	3,100
Calcium, %	1.15	0.64	1.15	0.64
Phosphorus (total), %	0.89	0.60	0.84	0.58
Phosphorus (available), %	0.66	0.32	0.66	0.32
Lysine, %	1.4	1.4	1.4	1.4
DL-Methionine, %	0.5	0.5	0.5	0.5
Analyzed				
Crude Protein, %	21.3	22.3	24.6	23.1
Calcium, %	1.51	0.85	1.26	0.76
Phosphorus (total), %	0.97	0.57	0.83	0.52

[1] Normal Corn (NC) + Industry Ca and P (Hi), Normal Corn (NC) + 15% Below NRC (Lo), Degermed-Dehulled Corn (DDC) + Industry Ca and P (Hi), Degermed-Dehulled Corn (DDC) + 15% Below NRC (Lo).

[2] Mineral composition (in g/kg of diet): zinc sulfate, 120; manganous sulfate, 120; copper sulfate, 10; calcium iodate, 2.5; cobalt sulfate, 1.0.

[3] Vitamins in amounts per kilogram of diet; vitamin A, 26,400 IU; vitamin D3, 8,000 IU; Vitamin E, 132 IU; Vitamin B12, 79.2 µg; riboflavin 26.4.

[4] Provided 0.3 mg Se per kilogram of diet.

Table 4.5. Dietary treatments[1] fed to male turkeys from 12-15 weeks of age.

	Diets			
Ingredient (%)	NC Hi	NC Lo	DDC Hi	DDC Lo
Corn Source	59.8	59.8	60.1	60.1
Soybean Meal	26.0	26.0	27.0	27.0
Poultry Meal				
Limestone	1.15	0.78	1.0	0.65
Dicalcium Phosphate	2.75	0.88	3.0	1.13
Poultry Fat	9.0	9.0	7.5	7.5
DL-Methionine	0.19	0.19	0.23	0.23
Salt	0.45	0.45	0.45	0.45
Minerals (TM-90)[2]	0.20	0.20	0.20	0.20
Vitamins (NCSU-90)[3]	0.20	0.20	0.20	0.20
Selenium Supplement[4]	0.04	0.04	0.04	0.04
Sand		2.25		2.23
Celite				
Total	100	100	100	100
Calculated Analysis				
Crude Protein, %	18.0	18.0	18.0	18.0
M. E. (kcal/kg)	3,100	3,100	3,100	3,100
Calcium, %	1.10	0.55	1.01	0.55
Phosphorus (total), %	0.82	0.49	0.78	0.43
Phosphorus (available), %	0.62	0.27	0.62	0.27
Lysine, %	1.0	1.0	1.0	1.0
DL-Methionine, %	0.5	0.5	0.5	0.5
Analyzed				
Crude Protein, %	18.1	19.1	17.7	16.1
Calcium, %	1.36	0.83	1.26	0.68
Phosphorus (total), %	0.84	0.54	0.80	0.47

[1] Normal Corn (NC) + Industry Ca and P (Hi), Normal Corn (NC) + 15% Below NRC (Lo), Degermed-Dehulled Corn (DDC) + Industry Ca and P (Hi), Degermed-Dehulled Corn (DDC) + 15% Below NRC (Lo).

[2] Mineral composition (in g/kg of diet): zinc sulfate, 120; manganous sulfate, 120; copper sulfate, 10; calcium iodate, 2.5; cobalt sulfate, 1.0.

[3] Vitamins in amounts per kilogram of diet; vitamin A, 26,400 IU; vitamin D3, 8,000 IU; Vitamin E, 132 IU; Vitamin B12, 79.2 µg; riboflavin 26.4.

[4] Provided 0.3 mg Se per kilogram of diet.

Table 4.6. Dietary treatments[1] fed to male turkeys from 15-18 weeks of age.

	Diets			
Ingredient (%)	NC Hi	NC Lo	DDC Hi	DDC Lo
Corn Source	66.7	66.7	66.7	66.7
Soybean Meal	18.6	18.6	20.0	20.0
Poultry Meal				
Limestone	1.2	0.7	1.1	0.6
Dicalcium Phosphate	2.4	0.7	2.6	1.0
Poultry Fat	9.0	9.0	7.5	7.5
DL-Methionine	0.13	0.13	0.15	0.15
Salt	0.43	0.43	0.48	0.48
Minerals (TM-90)[2]	0.20	0.20	0.20	0.20
Vitamins (NCSU-90)[3]	0.20	0.20	0.20	0.20
Selenium Supplement[4]	0.04	0.04	0.04	0.04
Sand		2.10		2.10
Celite	1.00	1.00	1.00	1.00
Total	100	100	100	100
Calculated Analysis				
Crude Protein, %	15.0	15.0	15.0	15.0
M. E. (kcal/kg)	3400	3400	3400	3400
Calcium, %	1.00	0.47	1.00	0.47
Phosphorus (total), %	0.60	0.50	0.60	0.40
Phosphorus (available), %	0.54	0.23	0.54	0.23
Lysine, %	0.9	0.9	0.9	0.9
DL-Methionine, %	0.5	0.5	0.5	0.5
Analyzed				
Crude Protein, %	17.0	18.1	14.6	18.4
Calcium, %	1.13	0.74	1.27	0.65
Phosphorus (total), %	0.82	0.51	0.81	0.40

[1] Normal Corn (NC) + Industry Ca and P (Hi), Normal Corn (NC) + 15% Below NRC (Lo), Degermed-Dehulled Corn (DDC) + Industry Ca and P (Hi), Degermed-Dehulled Corn (DDC) + 15% Below NRC (Lo).

[2] Mineral composition (in g/kg of diet): zinc sulfate, 120; manganous sulfate, 120; copper sulfate, 10; calcium iodate, 2.5; cobalt sulfate, 1.0.

[3] Vitamins in amounts per kilogram of diet; vitamin A, 26,400 IU; vitamin D3, 8,000 IU; Vitamin E, 132 IU; Vitamin B12, 79.2 µg; riboflavin 26.4.

[4] Provided 0.3 mg Se per kilogram of diet.

Table 4.7. Mean body weights (kg) for male turkeys fed 4 dietary treatments[1] raised to 18 weeks (wk) of age.

	Body Weights[2](kg)				
Treatment	3 wk	6 wk	9 wk	12 wk	18 wk
NC	0.72	2.60	5.66	9.42[a]	18.46
DDC	0.72	2.57	5.66	9.17[b]	18.12
P-value				0.0003	
Hi	0.73	2.59	5.75[a]	9.49[a]	18.41
Lo	0.72	2.57	5.57[b]	9.09[b]	18.17
P-value			0.02	0.002	
SEM	0.01	0.04	0.07	0.10	0.21

[1] Normal Corn (NC) + Industry Ca and P (Hi), Normal Corn (NC) + 15% Below NRC (Lo), Degermed-Dehulled Corn (DDC) + Industry Ca and P (Hi), Degermed-Dehulled Corn (DDC) + 15% Below NRC (Lo).

[2] SEM

[a, b] Means within a treatment and column lacking a common superscript differ significantly ($P \leq 0.05$).

Table 4.8. Feed conversion ratios for male turkeys fed 4 dietary treatments[1] raised to 18 weeks (wk) of age.

	Feed Conversion Ratio[2]				
Treatment	3 wk	6 wk	9 wk	12 wk	18 wk
NC	1.34	1.50	1.72	2.14[b]	2.64
DDC	1.37	1.54	1.73	2.23[a]	2.68
P-value				0.0002	
Hi	1.36	1.53	169[b]	2.16[b]	2.65
Lo	1.35	1.51	1.75[a]	2.21[a]	2.68
P-value			0.01	0.03	
SEM	0.02	0.03	0.02	0.02	0.04

[1] Normal Corn (NC) + Industry Ca and P (Hi), Normal Corn (NC) + 15% Below NRC (Lo), Degermed-Dehulled Corn (DDC) + Industry Ca and P (Hi), Degermed-Dehulled Corn (DDC) + 15% Below NRC (Lo).

[2] SEM

[a, b] Means within a treatment and column lacking a common superscript differ significantly ($P \leq 0.05$).

Table 4.9. Toe ash (%) and tibia breaking strength (kg/mm^2) measured of male turkeys at 3 and 6 weeks (wk) of age fed 4 dietary treatments[1].

	3 wk[2]		6 wk[3]	
Treatment	Toe Ash (%)	Tibia Breaking Strength (kg/mm^2)	Toe Ash (%)	Tibia Breaking Strength (kg/mm^2)
NC	15.4	10.5	16.5	11.2
DDC	16.3	10.2	16.9	11.0
Hi	16.6[a]	10.7	17.7	12.0[a]
Lo	15.1[b]	10.0	15.6	10.3[b]
P-value	0.04			0.0006
SEM	0.71	0.36	1.12	0.45

[1] Normal Corn (NC) + Industry Ca and P (Hi), Normal Corn (NC) + 15% Below NRC (Lo), Degermed-Dehulled Corn (DDC) + Industry Ca and P (Hi), Degermed-Dehulled Corn (DDC) + 15% Below NRC (Lo).

[2] SEM

[3] SEM

[a, b] Means within a treatment and column lacking a common superscript differ significantly ($P \leq 0.05$).

Table 4.10. AMEn (kcal/kg), ANR (%), and total fecal phosphorus (%) measured of male turkeys at 3 and 6 weeks (wk) of age fed 4 dietary treatments[1].

	3 wk[2]			6 wk[3]		
Treatment	AMEn (kcal/kg)	ANR (%)	Fecal P (%)	AMEn (kcal/kg)	ANR (%)	Fecal P (%)
NC	3005.9	68.4	1.9	2887.3	37.0	2.5
DDC	3039.1	67.1	1.9	2965.8	46.0	2.2
Hi	3048.3	69.8	2.4[a]	3058.8[a]	45.2	3.3[a]
Lo	2996.8	65.7	1.4[b]	2794.3[b]	37.8	1.4[b]
P-value			< 0.0001	0.009		0.0002
SEM	123.0	3.2	0.1	84.5	4.2	0.4

[1] Normal Corn (NC) + Industry Ca and P (Hi), Normal Corn (NC) + 15% Below NRC (Lo), Degermed-Dehulled Corn (DDC) + Industry Ca and P (Hi), Degermed-Dehulled Corn (DDC) + 15% Below NRC (Lo).

[2] SEM

[3] SEM

[a, b] Means within a treatment and column lacking a common superscript differ significantly ($P \leq 0.05$).

MANUSCRIPT V. THE USE OF DEGERMED-DEHULLED CORN FOR REARING TURKEY TOMS FROM 12 WEEKS OF AGE TO MARKET AGE.

ABSTRACT

An experiment was conducted to determine if feeding degermed-dehulled corn (DDC) to turkeys would support growth performance as well or better than those fed diets containing normal corn and would reduce phosphorus (P) excretion from turkeys raised to market age. Degermed-dehulled corn is produced by dry milling and results in the removal of 80% of the corn phytate P. Four hundred and eighty Nicholas Large White male turkeys were housed in a curtain sided house with 48 pens (10 birds per pen, 8 pens per treatment). Toms were fed typical starter, grower and finisher rations Birds were reared to 12 wk of age on the same rations. Treatments were fed from 12-20 wk and were in a factorial arrangement with two types of corn (NC and DDC) and three levels of available P (aP) per period. Feed and water were provided *ad libitium*. Diets were fed in mash form. Mean BW gain, feed consumption (by pen) and feed conversion (FCR) were determined at 16 and 20 wk. The following parameters were measured at 20 wk: apparent metabolizable energy (AMEn), apparent nitrogen retention (ANR), three-point tibia breaking strength, four-point tibia breaking strength, femur bone mineral density (BMD), femur bone mineral content (BMC), femur torsion, whole-body P and fecal P levels. Mean BW gain and FCR were improved by DDC at 16 wk but not at 20 wk. Tibia breaking strength was increased by DDC at 20 wk ($P \leq 0.05$; 7.2 kg/mm^2 vs. 6.4 kg/mm^2) using the 3 point bend method. Tibia breaking strength was significantly higher for turkeys fed NRC Lo at 20 wk ($P \leq 0.05$; 24.06 kg/mm^2) but only as measured using the 4 point bend method. Bone mineral density was significantly higher for turkeys fed DDC (0.43 g/cm^2) versus NC (0.41 g/cm^2). Bone mineral density and bone mineral content were both affected by aP level. Turkeys fed diets containing NRC and NRC Hi of recommended aP levels had significantly higher BMD and BMC versus feeding NRC Lo of NRC recommended aP levels. Torsion and AMEn were not significantly affected by treatments. Birds consuming NC had significantly higher ANR than birds consuming DDC ($P \leq 0.01$; 73.66% vs. 59.99%). Turkeys fed diets containing DDC had significantly higher whole body P versus feeding NC ($P \leq 0.01$; 0.15 kg vs. 0.12 kg). Fecal P was significantly affected by corn type, NRC level and the interaction of corn and NRC level. Turkeys fed diets containing NC had significantly higher fecal P versus feeding DDC ($P \leq 0.04$; 1.70% vs. 1.40%). Fecal P was reduced as NRC P levels decreased from NRC Hi to NRC Lo ($P \leq 0.0001$; 2.64%, 1.20%, and 0.85%). In conclusion, turkeys fed DDC in place of NC from 12 to 20 wk had similar growth performance with reduced fecal P and higher total retained P.

INTRODUCTION

Corn and soybean meal are the major feed sources in poultry diets. Approximately 60% of the phosphorus (P) in corn and soybean meal is in the form of phytate (Nelson et al., 1968, Reddy et al., 1982). Phytate P is poorly utilized by monogastric animals, which leads to the supplementation of diets with inorganic P to increase available P in the diets (Maenz and Classen, 1998). Phytate P is poorly available for poultry because they lack or are limited in the endogenous phytase needed to degrade phytate effectively. Therefore, a proportion of dietary P cannot be used by the bird and is excreted into the feces (Van der Klis et al., 1997). Concern over effects of excreted P on the eutrophication of surface waters (Sharpley, 1999), illustrates a need to provide adequate P to sustain economic performance of poultry while decreasing fecal P excretion.

Improving the availability of phytate P would reduce the need to supplement feed with inorganic P which would enable a reduction of dietary P and result in a lower P excretion. Various dietary methods such as formulating diets closer to the optimal nutritional requirements, inclusion of phytase, using genetically and mechanically altered feed ingredients have been studied to increase P availability and decrease fecal P. Simons et al., (1990) demonstrated phytase inclusion poultry diets increased dietary P availability up to 65% and decreased P excretion by 50%. Other approaches to reduce fecal P include: feeding closer to recommended NRC levels (Yan et al., 2003), phase feeding (Dhandu and Angel, 2003), developing genetically modified feedstuffs to have high available P content (Raboy, 1997), and mechanically modified feedstuffs with altered levels of phytate bound P.

Degermed-dehulled corn (DDC), produced from dry milling corn, is a mechanically altered product of corn that provides lower phytate P levels and higher energy content, as well as lower fiber content (Moeser et al., 2002). Approximately 90% of phytate P in corn is located within the germ portion of the seed (Harland and Oberleas, 1996). The dry milling process can involve a series of steps that are designed to physically separate the corn kernel into its anatomical constituents of endosperm, hull, and germ (Moeser et al., 2002). The removal of the germ removes a large portion of the indigestible portion of phytate P (Applegate, 2005). The substitution of NC with DDC may reduce the amount of total P in the feed and feces by reducing the phytate bound P in the diet. The objective of this study was to determine the effect of feeding mechanically modified degermed-dehulled corn with three varying NRC levels of Ca and P on male turkey growth performance and fecal P excretion reared to market age.

MATERIALS AND METHODS

Twelve week old Nicholas Large White male turkeys (480) were randomly assigned to 48 pens (10 birds per pen) in a curtain sided house. There were 8 pens per treatment and six grower rations. Dietary treatments were randomly assigned to 2 pens in each block and the pen served as the experimental unit. The dietary treatments were typical corn-soy based diets meeting NRC (1994) nutrient recommendations with two types of corn (normal corn and degermed-dehulled corn) and three levels of dietary aP (Table 5.1, Table 5.2). Treatments consisted of 1.) normal corn (NC) plus available phosphorus (aP) at 0.15% (12 to 16 wk) and 0.18% (16 to 20 wk) above recommended NRC levels (NC NRC Hi), 2.) NC plus aP at recommended NRC levels (NC NRC), 3.) NC with no added P (NC NRC Lo), 4.) DDC plus aP at 0.15% (12 to 16 wk) and 0.18% (16 to 20 wk) above recommended NRC levels (DDC NRC

Hi), 5.) DDC plus aP at recommended NRC levels (DDC NRC), 6.) DDC plus P added to equal the tP in NC NRC Lo (DDC NRC Lo). Diets were formulated to maintain Ca:aP at approximately 2:1. Diets were analyzed to determine crude protein, calcium, and total P of formulated diets on an as fed basis (Table 5.1, Table 5.2). Feed and water were provided *ad libitium*.

The following parameters were measured at 16 and 20 wk: body weight (BW) feed consumption (by pen), and feed conversion ration (FCR) was calculated for each 4 wk period and for 12-20 wk. The following parameters were also measured at 20 wk: apparent metabolizable energy (AMEn), apparent nitrogen retention (ANR), three-point tibia breaking strength, four-point tibia breaking strength, femur bone mineral density (BMD), femur bone mineral content (BMC), femur torsion and fecal P (%) levels. An inert digestible marker, Celite^{TM} (Celite Corp., Lompar, CA), was used to estimate the digestibility of dietary nutrients (Scott and Boldaji, 1997). The ratio of the marker in the diet to the amount of marker in the excreta indicates the digestibility of the diet by the bird.

BIOMECHANICAL PROPERTIES OF BONE

At 20 wk, 1 bird per pen was sacrificed and femurs and tibias were collected and analyzed for biomechanical properties.

Physical bone characteristics were determined by the three-point bending test. The load and the stress at failure, the strain and the Young’s modulus (modulus of elasticity) were determined using a three-point flexural bending with a total distance of 120.73 mm between the two supporting ends. The load is defined as force in kilograms per square millimeter of cross-sectional area and represents bone strength. The modulus measures the stiffness of the bone as it relates to stress and strain (Rath et al., 1999). Stress represents internal resistance to deformity and strain represents the percentage of deformity (Einhorn, 1996). The rate of loading was kept constant at 30 mm/min.

Bending properties of the turkey tibia were tested in four-point bending using an axial servo-hydraulic load frame (858 Mini Bionix II, MTS Systems Inc., Minneapolis, MN). The tibias were assumed to have a hollow elliptical cross section with a uniform wall thickness as described by Cubo and Casinos (1998, 2000). The diameters of the major axis and minor axis were measured and the bones were tested with the resulting moment applied about the major axis. Four-point bending tests were carried out as described by Ferket et al., (2009) with a lower support span of 160 mm. The load was applied through two upper supports spaced 76.5 mm apart at a loading rate of 30 mm/min to failure. The cortical wall thickness was measured at four points along the cross section on each side of the failure and then averaged to determine the average thickness. The force and displacement at the point of application of the force were recorded. The different biomechanical parameters were calculated according to the following formulas:

Area Moment of Inertia (I_x)

$I_x = 1/4\ \pi\ [(r_{major})(r_{minor})^3 - (r_{major} - t)(r_{minor} - t)^3]$

r_{major} – radius of the major axis of the ellipse forming the outer cortical boundary, this is the axis about which being is taking place.

r_{minor} – radius of the minor axis of the ellipse forming the outer cortical boundary.

t – average cortical thickness.

The applied moment (M) for four-point bending:

$$M = \frac{\frac{F_{max}}{2} \quad \frac{L_1 - L_u}{2}}{}$$

F_{max} = Maximum applied force

L_1 = Lower support span

L_u = Upper support span

Maximum Bending Stress (σ_{max})

$$\sigma_{max} = \frac{M \quad r_{minor}}{I_x}$$

Torsional properties of turkey femurs were tested as described by Ferket et al., (2009) using an axial-torsion servohydraulic load frame (858 Mini Bionix II, MTS Systems Inc., Minneapolis, MN). Femurs were assumed to have a hollow elliptical cross section with inner and outer edges forming similar ellipses. The ends of the femurs were potted in epoxy (Bondo, Bondo Corporation, Atlanta, GA) to allow them to be secured into the load frame. Screws were driven into the each end of the femur leaving approximately 10 mm of the screw shaft exposed to help ensure that the bones were held tightly within the epoxy. The distal end was held fixed in the load frame and the proximal end was rotated in external rotation at a rate of 10º/sec until failure. The applied torque and angular displacement were recorded. The cortical wall thickness was measured at four points along the cross section on each side of the failure and then averaged to determine the average thickness. The different biomechanical parameters were calculated according to the following formulas:

Maximum Shear Stress (τ_{max}):

$$\tau_{max} = \frac{T_{max}}{Q}$$

T_{max} = Maximum Torque applied during test

$$Q = \frac{\pi (r_{major})(r_{minor})^2(1-k^4)}{2}$$

For similar ellipses: inner elliptical boundary = k*(outer elliptical boundary)

Densitometric readings were obtained on the turkey femur using dual-energy x-ray absorptiometry (DEXA) according to methods by Schreiweis et al., (2003). Densitometric readings are expressed in terms of grams of mineral adjusted for the area scanned, giving bone mineral density (BMD) in g/cm^2 (Johnston et al., 1991). Traditionally, invasive techniques have been used to monitor bone quality; however, this does not allow for sequential observations of bone quality. In 2003, Schreiweis and others adapted the use of DEXA, noninvasive method to determine bone quality, for measuring mineral content (BMC) for use in chickens. The BMD, determined using DEXA, is a combination of the thickness and density of the object this correlates with the mechanical properties of bone, which are dependent on the thickness and geometry of bone (Faulkner et al., 1991; Schreiweis et al., 2005).

Data were analyzed using GLM for treatment effect and linear regression analysis within NRC levels. Differences among treatment means were partitioned using the least square means procedure of SAS (SAS Institute, Inc., 1992). Statements of significance are based on $P \leq 0.05$ unless otherwise stated.

RESULTS AND DISCUSSION

Diets formulated with NC and higher levels of NRC recommended Ca and P had 58% less total P (tP) than calculated in addition to reduced protein content. This may have contributed to the low mean BW gain (1.9 kg) from 12 to 16 wk. Therefore, dietary treatments containing NRC Hi were not used when analyzing mean BW gain, feed consumption, or FCR. Period mean BW gain from 12 to 16 wk was significantly affected by the interaction of corn source and aP level (Table 5.3). Turkeys fed DDC and no added P had significantly lower BW gain (3.6 kg) versus all other treatments. Feed consumed from 12 to 16 wk was not significantly affected by corn source, aP level, or the interaction of corn source and aP level (Table 5.4). Period FCR was significantly affected by the interaction of corn source and aP level from 12 to 16 wk (Table 5.5). Turkeys fed DDC and NRC had significantly better FCR (2.8) versus all other treatments. Period mean BW gain from 16 to

20 wk was significantly affected by the interaction for corn source and aP level. Turkeys fed DDC plus NRC Lo (3.5 kg) had significantly higher mean body weight than all other treatments (Table 5.3). Feed consumed from 16 to 20 wk was significantly higher when turkeys were fed NC (32.0 kg). Period FCR was significantly affected by the interaction of corn source and aP level from 16 to 20 wk (Table 5.5). Turkeys fed DDC plus NRC Lo had significantly better FCR ($P \leq 0.01$; 3.6) versus all other treatments. Cumulative mean BW gain was not significantly affected by corn source, aP level, or the interaction of corn source and aP level. Cumulative feed consumption from 12 to 20 wk ($P \leq 0.02$; NC-69.7 kg vs. DDC-65.9 kg; Table 5.4) and FCR from 12 to 20 wk ($P \leq 0.003$; NC-4.1 vs. DDC-3.7; Table 5.5) were significantly higher when turkeys were fed NC versus DDC.

Feeding available P (aP) at NRC recommendations or NRC recommendations reduced by 0.15% to turkey hens grown to market age had no effect on BW gain or feed conversion over the combined 15 week period (Ledoux et al., 1995). In contrast, Thompson et al, (2002) fed industry nPP diets, NRC (1994) diets, or 83% of the NRC (1994) requirement for P to turkey toms grown to 18 wk and reported no differences observed in growth between industry and NRC diets; however, birds fed diets containing 83% of NRC were substantially lighter. This agrees with, Roberson et al., (2000) who reported impaired growth from 3 to 17 wk when birds were fed 75% of NRC recommended nPP which was lower than NRC levels used by Thompson et al., 2002; Ledoux et al., 1995 or the current study. However, Atia et al., 2000 fed 73% of NRC recommended nPP and reported BW gain was similar to the control diet (110% NRC Ca and nPP). It was at 52% of nPP (90% Ca) inferior performance was reported (Atia et al., 2000). The lack in dietary effect in the current study and in other studies suggests the turkeys' requirement for growth may be lower than NRC recommendation.

Tibia breaking strength was affected by corn source and Ca and P levels at 20 wk. The 3-point and the 4-point bend methods were used to analyze tibia breaking strength; however, these two methods demonstrated different dietary effects on turkey tibias at 20 wk. The 3-point bend method resulted in increased tibia breaking strength when turkeys were fed DDC versus NC at 20 wk (Table 5.6). The 4-point bend method resulted in increased tibia breaking strength when turkeys were fed varying levels of NRC aP (Table 5.6). Turkeys fed NRC Lo (24.06 kg/mm^2) resulted in significantly higher breaking strength using the 4-point bend method than those fed NRC (21.94 kg/mm^2). Similarly, Turkeys fed 73% of NRC aP with 100% Ca had reported bone ash, strength, and density similar birds fed to the control diet of 110% NRC Ca and nPP (Atia et al., 2000). Others have reported impaired bone mineralization, significantly lower tibia mineralization and substantially lower strength measurements when birds were fed 52-83% of NRC recommended aP (Roberson et al., 2004; Roberson et al., 2000; Thompson et al, 2002; Atia et al., 2000).

Traditionally, invasive techniques have been used to monitor bone quality; however, this does not allow for sequential observations of bone quality. In 2003, Schreiweis and others adapted the use of dual-energy x-ray absorptiometry (DEXA), a noninvasive method to determine bone quality, for measuring mineral content (BMC) for use in chickens. Schreiweis et al., (2005) compared densitometric scans with traditional invasive measurements of bone strength, including bone breaking strength measurements and bone ash weight, under a normal dietary regimen as well as in hens fed varying levels of dietary Ca. Densitometric scans of live birds and excised bones were positively correlated with bone breaking force and bone ash. As hens consumed diets with decreasing Ca levels, the BMD and BMC of live birds and excised bones, and bone breaking traits of excised bones decreased linearly. This demonstrated the ability to use densitometric values, a noninvasive and less time consuming method, as a way to determine bone quality without sacrificing the live bird.

In the current study, femurs collected at 20 wk were used to conduct densitometric scans and torsion tests. Densitometric scans were affected by corn source and NRC level. Turkeys fed DDC had significantly higher BMD (0.43 g/cm^2) versus those fed NC (0.41 g/cm^2) with no affect on BMC (Table 5.7). The aP level affected BMD and BMC similarly. Turkeys fed diets containing NRC or NRC Hi of recommended NRC aP levels had significantly higher BMD and BMC than those fed NRC Lo (Table 5.7). This agrees Schreiweis et al., (2005) and Angel et al., (2006) who reported BMD and BMC decreased as Ca and P levels decreased below NRC recommendations. In contrast, Atia et al., (2000) reported turkeys fed 73% of NRC recommended nonphytate P had similar bone density to those fed 110% of NRC recommended nonphytate P.

Resistance to breaking in a 3- or 4-point bending assay has long been a marker for bone strength (Rath et al., 1999, 2000). To better understand the treatment effects on bone development and strength, it is important to also evaluate biomechanical parameters of bone (Oviedo-Rondon et al., 2006). Spiral femoral fractures that can occur spontaneously in the field can be replicated in the laboratory using torsion test (Crepso et al., 2000; Oviedo-Rondón et al., 2006). Torsion testing on femur bones collected at 20 wk was not affected by corn source, a P level or an interaction of the two. The lack of dietary treatment effect on torsion testing suggests the birds' requirement for bone mineralization had been met prior to 20 wk by dietary treatments.

At 20 wk, one bird per pen was sacrificed to determine whole body P content. The substitution of DDC for NC increased the available P present in the diet. However, chemical analysis of NC plus NRC Hi resulted in decreased levels of tP and protein from the original formulation. Therefore, dietary treatments containing NRC Hi were not used when analyzing P consumed, whole body P, or the difference between P consumed and whole body P. Phosphorus consumed from day of hatch to 20 wk nor the difference between P consumed and whole body P were significantly affected by corn source, aP level, or the interaction of corn source and aP level. Whole body P determined on analyzed tP was significantly affected by corn type (Table 5.8). Turkeys fed diets containing DDC had significantly higher whole body P versus feeding NC ($P \leq 0.01$; 0.15 kg vs. 0.12 kg).

At 20 wk, fecal samples were collected for three days to determine AMEn, ANR, and total fecal P. The AMEn was not significantly affected by dietary treatments (Table 5.9). Birds consuming NC had significantly higher ANR than birds consuming DDC (Table 5.9). Fecal P was significantly affected by the interaction of corn source and NRC level (Table 5.10). There was a significant linear decrease in fecal P as NRC recommended aP levels decreased when fed NC or DDC. This result agrees with reports that turkey hens fed lower levels of available P had significantly lower percent litter P at 15 wk (Ledoux et al, 1995). Another explanation for reductions in fecal P could be associated with rates in feed consumption. It is known that consumption of larger amounts of feed with increased dietary P will increase fecal P (Waldroup, 1999). The P in DDC is approximately 5 to 6 times more available than NC and can significantly reduce the amount of P excreted in poultry waste. However, additional studies are needed to determine these effects.

In comparing DDC as a replacement for corn when fed to turkeys raised to market age, there were no consistent differences among any parameters tested. However, feeding aP at NRC or NRC Lo had significant effects on densitometric scans and fecal P. Results from this study suggest feeding DDC results in performance equal to NC and reducing Ca and P levels below recommended NRC levels can reduce fecal P without impairing performance.

REFERENCES

Angel, R., W. W. Saylor, A. D. Mitchell, W. Powers, and T. J. Applegate, 2006. Effect of dietary phosphorus, phytase, and 25-hydroxycholecalciferol on broiler chicken bone mineralization, litter phosphorus, and processing yields. Poult. Sci. 85:1200-1211.

Applegate, T. J., 2005. The nutritional value of dehulled-degermed corn for broiler chickens and its impact on nutrient excretion. Poult. Sci. 84:742-747.

Atia, F. A., P. E. Waibel, I. Hermes, C. W. Carlson, and M. M. Walser, 2000. Effect of dietary phosphorus, calcium, and phytase on performance of growing turkeys. Poult. Sci. 79:231-239.

Crespo, R., S. M. Stover, K. T, Taylor, R. P. Chin, and H. L. Shivaprasad, 2000. Morphometric and mechanical properties of femora in young adult male turkeys with femoral fractures. Poult. Sci. 79:602-608.

Cubo, J., and A. Casinos, 1998. Biomechanical significance of cross-sectional geometry of avian long bones. Eur. J. Morphol. 36:19-28.

Cubo, J., and A. Casinos, 2000. Mechanical properties and chemical composition of avian long bones. Eur. J. Morphol. 28:112-121.

Dhandu, A. S. And R. Angel, 2003. Broiler nonphytin phosphorus requirement in the finisher and withdrawal phases of a commercial four-phase feeding system. Poult. Sci. 82:1257-1265.

Einhorn, T. A., 1996. Biomechanics of bone. In: Principles of Bone Biology, J. P. Bilezikian, L. G. Raisz, and G. A. Rodan, ed. Academic Press, San Diego. CA.

Faulkner, K. G., C. C. Gluer, S. Majumdar, P. Lang, K. Engleke, and H. K. Genant, 1991. Noninvasive bone measurements of bone mass, structure, and strength: Current methods and experimental techniques. AJR AM. J. Roentgenol. 157:1229-1237.

Ferket, P. R., E. O. Oviedo-Rondón, P. L. Mente, D. V. Bohórquez, A. A. Santos, Jr., J. L. Grimes, J. D. Richards, J. J. Dibner, and V. Felts, 2009. Organic trace minerals and 25-hydroxycholecalciferol affect performance characteristics, leg abnormalities, and biomechanical properties of leg bones of turkeys. Poult. Sci. 88:118-131.

Harland, F., and D. Oberleas, 1996. Impact of phytate on nutrient availability, In: Phytase in Animal Nutrition and Waste Management (Coelho, M. B. and Kornegay, E. T., Eds), BASF Corporation, Mount Olive, NJ.

Johnston, C. C., C. W. Slemenda, and L. J. Melton, 1991. Clinical use of bone densitometry. Current Concepts. 324:1105-1109.

Ledoux, D. R., K. Zyla, and T. L. Veum, 1995. Substitution of phytase for inorganic phosphorus for turkey hens. J. Appl. Poultry Res. 4:157-163.

Maenz, D. D. and H. L. Classen, 1998. Phytase activity in the small intestinal brush border membrane of the chicken. Poult. Sci. 77:557-563.

Moeser, A. J., I. B. Kim, E. van Heugten, and T. van Kempen, 2002. The nutritional value of degermed, dehulled corn for pigs and its impact on the gastrointestinal tract and nutrient excretion. J. Anim. Sci. 80:2629-2638.

National Research Council, 1994. Nutrient requirements of poultry. 9th rev. ed. National Academy Press, Washington, DC.

Nelson, T. S., L. W. Ferrara, and N. L. Storer, 1968. Phytate phosphorus content of feed ingredients derived from plants. Poult. Sci. 47:1372.

Oviedo-Rondón, E. O., P. R. Ferket, P. R. Mente, B. D. X. Lascelles, H. J. Barnes, D V. Bohórquez, and J. L. Grimes, 2006. Biomechanical factors that influence spiral femoral fractures of turkeys. CD Proc. AVMA-AAA Meet., Honolulu, Hawaii (Abstr.).

Raboy, V., 1997. Accumulation and storage of phosphate and minerals. Pages 441-477 in: Advances in Cellular and Molecular Biology of Plants. Vo. 4. Cellular and Molecular Biology of Plant Seed Development. B. A. Larkins and I. K. Vasil, ed. Kluwer Publishers, Dordrecht, The Netherlands.

Rath, N. C., J. M. Balog, W. E. Huff, G. R. Huff, G. B. Kulkarni, and J. F. Tierce, 1999. Comparative differences in the composition and biomechanical properties of tibiae of seven- and seventy-two-week-old male and female broiler breeder chickens. Poult. Sci. 78:1232-1239.

Rath, N. C., G. R. Huff, W. E. Huff, and J. M. Balog, 2000. Factors regulating bone maturity and strength in poultry. Poult. Sci. 79:1024-1032.

Reddy, N. R., S. K. Sathe, and D. K. Salunkhe, 1982. Phytates in legumes and cereals. In: Advances in Food Research, C. O. Chichester, E. M. Mrak, and G. F. Stewart, ed. Academic Press, New York, NY.

Roberson, K. D. M. W. Klunzinger, and R. A. Charbeneau 2004. Benefit of feeding dietary calcium and nonphytate phosphorus levels above National Research Council recommendations to tom turkeys in the growing-finishing phases. Poultry Sci. 83:689-695.

Roberson, K. D., M. W. Klunzinger, M. F. Ledwaba, A. P. Rahn, M. W. Orth, R. M. Fulton, and B. P. Marks, 2000. Effects of dietary calcium and phosphorus regimen on growth performance, bone strength, and carcass quality and yield of Large White tom turkeys. Poult. Sci. 79(Suppl. 1):68.

SAS Institute, 1992. SAS User’s Guide. Version 6.08. SAS Institute Inc., Cary, NC.

Schreiweis, M. A., J. I. Orban, M. C. Ledur, and P. Y. Hester, 2003. The use of densitometry to detect differences in bone mineral density and content of live White Leghorns fed varying levels of dietary calcium. Poult. Sci. 82:1292-1301.

Schreiweis, J., I., M. C. Orban, M. C. Ledur, D. E. Moody, and P. Y. Hester, 2005. Validation of dual-energy x-ray absorptiometry in live white leghorns. Poult. Sci. 84:91-99.

Sharpley, A., 1999. Symposium: Reducing the environmental impact of poultry production: Focus on phosphorus. Poult. Sci. 78:660-673.

Simons, P. C., M. A. J. Versteegh, A. W. Jongbloed, P. A. Kemme, P. Slump, K. D. Bos, M. G. E. Wolters, R. F. Beudeker, and G. J. Verschoor, 1990. Improvement of phosphorus availability by microbial phytase in broilers and pigs. Br. J. Nutr. 64:525-540.

Thompson, K. L., T. J. Applegate, R. Angel, K. Ondracek, and P. Jaynes, 2002. Effect of phosphorus level, 25-hydroxycholecalciferol (HyD), and phytase supplementation on performance of male turkeys from 0 to 18 weeks of age. Poult. Sci. 81(Suppl. 1):13.

Van der Klis, J. D., H. A. J. Versteegh, P. C. M. Simons, and A. K. Kies, 1997. The efficacy of phytase in corn-soybean meal-based diets for laying hens. Poult. Sci. 76:1535-1542.

Waldroup, P. W., 1999. Nutritional approached to reducing phosphorus excretion by poultry. Poultry Sci. 78:683-691.

Yan, F., C, A, Fritts, P. W. Waldroup, H. L. Stillborn, D. Rice, R. C. Crum, Jr. and V. Raboy, 2003. Comparison of normal and high available phosphorus corn with and without phytase supplementation in diets for male large white turkeys grown to market weights. International Journal of Poultry Science 2 (2): 83-90.

Table 5.1. Dietary treatments[1] fed to male turkeys from 12-16 weeks of age.

Ingredient (%)	NC NRC Hi	NC NRC	NC NRC Lo	DDC NRC Hi	DDC NRC	DDC NRC Lo
Corn Source	62.5	62.5	62.5	62.5	62.5	62.5
Soybean Meal	21.6	21.6	21.6	23.4	23.5	23.5
Poultry Meal						
Limestone	0.9	0.8	0.3	0.7	0.7	0.3
Dicalcium Phosphate	2.6	1.7		2.9	2.0	0.7
Poultry Fat	11.0	11.0	11.0	9.1	9.1	9.1
DL-Methionine	0.10	0.10	0.10	0.13	0.13	0.13
Salt	0.45	0.45	0.45	0.45	0.45	0.45
Minerals (TM-90)[2]	0.20	0.20	0.20	0.20	0.20	0.20
Vitamins (NCSU-90)[3]	0.20	0.20	0.20	0.20	0.20	0.20
Selenium Supplement[4]	0.10	0.10	0.10	0.10	0.10	0.10
Sand		1.0	3.2		0.82	2.5
Celite						
Total	100	100	100	100	100	100
Calculated Analysis						
Crude Protein, %	16.2	16.2	16.2	16.5	16.5	16.5
M. E. (kcal/kg)	3,498	3,498	3,498	3,498	3,498	3,498
Calcium, %	1.01	0.77	0.21	1.00	0.80	0.36
Phosphorus (total), %	0.80	0.63	0.32	0.73	0.56	0.32
Phosphorus (available), %	0.54	0.39	0.10	0.55	0.40	0.17
Lysine, %	1.04	1.04	1.04	1.03	1.04	1.04
DL-Methionine, %	0.37	0.37	0.37	0.36	0.36	0.36
Analyzed						
Crude Protein, %	11.3	16.6	16.4	16.9	16.5	18.3
Calcium, %	0.60	0.66	0.33	0.94	0.92	0.47
Phosphorus (total), %	0.46	0.62	0.39	1.00	0.68	0.39

[1] Normal corn (NC) + available phosphorus (aP) at 0.15% NRC (NC NRC Hi), NC plus aP at NRC (NC NRC), NC with no added P (NC NRC Lo), DDC + aP at 0.15% NRC (DDC NRC Hi), DDC + aP at NRC (DDC NRC), DDC + P added to equal the tP in NC NRC Lo (DDC NRC Lo).

[2] Mineral composition (in g/kg of diet): zinc sulfate, 120; manganous sulfate, 120; copper sulfate, 10; calcium iodate, 2.5; cobalt sulfate, 1.0.

[3] Vitamins in amounts per kilogram of diet; vitamin A, 26,400 IU; vitamin D3, 8,000 IU; Vitamin E, 132 IU; Vitamin B12, 79.2 µg; riboflavin 26.4.

[4] Provided 0.3 mg Se per kilogram of diet.

Table 5.2. Dietary treatments[1] fed to male turkeys from 16-20 weeks of age.

Ingredient (%)	NC NRC Hi	NC NRC	NC NRC Lo	DDC NRC Hi	DDC NRC	DDC NRC Lo
Corn Source	66.2	66.2	66.2	66.3	66.3	66.3
Soybean Meal	18.0	18.0	18.0	20.2	20.2	20.2
Poultry Meal						
Limestone	1.0	0.7	0.2	0.6	0.6	0.2
Dicalcium Phosphate	2.5	1.4		2.7	1.6	0.5
Poultry Fat	11.0	11.0	11.0	8.9	8.9	8.9
DL-Methionine	0.10	0.10	0.10	0.15	0.15	0.15
Salt	0.45	0.45	0.45	0.45	0.45	0.45
Minerals (TM-90)[2]	0.20	0.20	0.20	0.20	0.20	0.20
Vitamins (NCSU-90)[3]	0.20	0.20	0.20	0.20	0.20	0.20
Selenium Supplement[4]	0.10	0.10	0.10	0.10	0.10	0.10
Sand		1.4	3.3		1.1	2.6
Celite	0.20	0.20	0.20	0.20	0.20	0.20
Total	100	100	100	100	100	100
Calculated Analysis						
Crude Protein, %	14.1	14.1	14.1	14.2	14.2	14.2
M. E. (kcal/kg)	3,536	3,536	3,536	3,536	3,536	3,536
Calcium, %	1.02	0.66	0.16	0.91	0.67	0.28
Phosphorus (total), %	0.72	0.52	0.26	0.67	0.47	0.26
Phosphorus (available), %	0.50	0.32	0.08	0.51	0.33	0.14
Lysine, %	0.86	0.86	0.86	0.86	0.86	0.86
DL-Methionine, %	0.36	0.36	0.36	0.36	0.36	0.36
Analyzed						
Crude Protein, %	18.7	14.8	16.1	15.5	15.7	16.0
Calcium, %	1.14	0.85	0.37	0.86	0.83	0.41
Phosphorus (total), %	0.86	0.65	0.37	0.76	0.60	0.39

[1] Normal corn (NC) + available phosphorus (aP) at 0.18% NRC (NC NRC Hi), NC + aP at NRC (NC NRC), NC with no added P (NC NRC Lo), DDC + aP at 0.18% NRC (DDC NRC Hi), DDC + aP at NRC (DDC NRC), DDC + P added to equal the tP in NC NRC Lo (DDC NRC Lo).

[2] Mineral composition (in g/kg of diet): zinc sulfate, 120; manganous sulfate, 120; copper sulfate, 10; calcium iodate, 2.5; cobalt sulfate, 1.0.

[3] Vitamins in amounts per kilogram of diet; vitamin A, 26,400 IU; vitamin D3, 8,000 IU; Vitamin E, 132 IU; Vitamin B12, 79.2 µg; riboflavin 26.4.

[4] Provided 0.3 mg Se per kilogram of diet.

Table 5.3. Period and cumulative mean body weight gain (kg) of male turkeys raised from 12 to 20 weeks (wk) of age fed 6 dietary treatments[1].

	12-16 wk[2]			16-20 wk[3]			Cumulative 12-20 wk[4]		
aP Level	NC	DDC	$\bar{x}$	NC	DDC	$\bar{x}$	NC	DDC	$\bar{x}$
NRC Hi[5]	1.9	4.3	3.1	4.4	3.4	3.9	6.4	7.7	7.1
NRC	4.2[a]	4.6[a]	4.4[x]	3.0[b]	2.7[b]	2.9[y]	7.1	7.3	7.2
NRC Lo	4.1[a]	3.6[b]	3.9[y]	2.9[b]	3.5[a]	3.2[x]	7.0	7.1	7.1
$\bar{x}^6$	4.2	4.1		3.0	3.1		7.1	7.2	

[1] Normal corn (NC) + available phosphorus (aP) at 0.15% (12 to 16 wk) and 0.18% (16 to 20 wk) above NRC (NC NRC Hi), NC + aP at NRC (NC NRC), NC with no added P (NC NRC Lo), DDC + aP at 0.15% (12 to 16 wk) and 0.18% (16 to 20 wk) above NRC (DDC NRC Hi), DDC + aP at NRC (DDC NRC), DDC + P added to equal the tP in NC NRC Lo (DDC NRC Lo).

[2] SEM = 0.16; NRC, $P \leq 0.007$; Corn X NRC, $P \leq 0.01$

[3] SEM = 0.17; NRC, $P \leq 0.02$; Corn X NRC, $P \leq 0.007$

[4] SEM = 0.19

[5] Treatments containing NRC Hi were not used in the period or cumulative mean BW analysis; however the values were provided here as comparison.

[6] Corn source means were calculated using NRC and NRC Lo

[a-c] Means within a period lacking a common superscript differ significantly ($P \leq 0.05$).

[x, y] Means within a period lacking a common superscript differ significantly ($P \leq 0.05$).

Table 5.4. Period and cumulative feed consumed (kg) by male turkeys raised from 12 to 20 weeks of age fed 6 dietary treatments[1].

	12-16 wk[2]			16-20 wk[3]			Cumulative 12-20 wk[4]		
aP Level	NC	DDC	$\bar{x}$	NC	DDC	$\bar{x}$	NC	DDC	$\bar{x}$
NRC Hi[5]	23.2	28.6	25.9	35.2	31.2	33.2	66.4	67.9	67.2
NRC	29.4	28.6	29.0	30.9	30.7	30.8	68.4	67.3	67.9
NRC Lo	29.6	28.1	28.9	33.2	28.4	30.8	70.9	64.5	67.7
$\bar{x}$[6]	29.5	28.4		32.0[x]	29.6[y]		69.7[x]	65.9[y]	

[1] Normal corn (NC) + available phosphorus (aP) at 0.15% (12 to 16 wk) and 0.18% (16 to 20 wk) above NRC (NC NRC Hi), NC + aP at NRC (NC NRC), NC with no added P (NC NRC Lo), DDC + aP at 0.15% (12 to 16 wk) and 0.18% (16 to 20 wk) above NRC (DDC NRC Hi), DDC + aP at NRC (DDC NRC), DDC + P added to equal the tP in NC NRC Lo (DDC NRC Lo).

[2] SEM = 0.65

[3] SEM = 1.25; Corn, $P \leq 0.05$

[4] SEM = 1.53; Corn, $P \leq 0.02$

[5] Treatments containing NRC Hi were not used in the period or cumulative feed consumption analysis; however the values were provided here as comparison.

[6] Corn source means were calculated using NRC and NRC Lo

[x, y] Means within a period lacking a common superscript differ significantly ($P \leq 0.05$).

Table 5.5. Period and cumulative feed conversion ratios of male turkeys raised from 12 to 20 weeks (wk) of age fed 6 dietary treatments[1].

	12-16 wk[2]			16-20 wk[3]			Cumulative 12-20 wk[4]		
aP Level	NC	DDC	$\bar{x}$	NC	DDC	$\bar{x}$	NC	DDC	$\bar{x}$
NRC Hi[5]	5.6	3.0	4.3	3.4	4.3	3.8	4.2	3.7	4.0
NRC	3.2[a]	2.8[b]	3.0[y]	4.6[a]	4.6[a]	4.6[x]	4.0	3.7	3.9
NRC Lo	3.3[a]	3.3[a]	3.3[x]	4.3[a]	3.6[b]	4.0[y]	4.2	3.8	4.0
$\bar{x}$[6]	3.3	3.1		4.5[x]	4.1[y]		4.1[x]	3.7[y]	

[1] Normal corn (NC) + available phosphorus (aP) at 0.15% (12 to 16 wk) and 0.18% (16 to 20 wk) above NRC (NC NRC Hi), NC + aP at NRC (NC NRC), NC with no added P (NC NRC Lo), DDC + aP at 0.15% (12 to 16 wk) and 0.18% (16 to 20 wk) above NRC (DDC NRC Hi), DDC + aP at NRC (DDC NRC), DDC + P added to equal the tP in NC NRC Lo (DDC NRC Lo).

[2] SEM = 0.17; NRC, $P \leq 0.01$; Corn X NRC, $P \leq 0.03$

[3] SEM = 0.13; Corn, $P \leq 0.02$; NRC, $P \leq 0.0001$; Corn X NRC, $P \leq 0.01$

[4] SEM = 0.10; Corn, $P \leq 0.003$

[5] Treatments containing NRC Hi were not used in the period or cumulative FCR analysis; however the values were provided here as comparison.

[6] Corn source means were calculated using NRC and NRC Lo.

[a-c] Means within a period lacking a common superscript differ significantly ($P \leq 0.05$).

[x, y] Means within a period lacking a common superscript differ significantly ($P \leq 0.05$).

Table 5.6. Tibia breaking strength (kg/mm^2) measured of male turkeys at 20 weeks of age fed 6 dietary treatments[1].

	3 Point Tibia Breaking Strength[2] (kg/mm^2)			4 Point Tibia Breaking Strength[3] (kg/mm^2)		
aP Level	NC	DDC	$\bar{x}$	NC	DDC	$\bar{x}$
NRC Hi	6.56	6.93	6.74	24.40	22.08	23.24^{xy}
NRC	7.03	7.60	7.32	21.77	22.11	21.94^{y}
NRC Lo	5.66	7.26	6.46	24.38	24.95	24.66^{x}
$\bar{x}$	6.42^{y}	7.26^{x}		23.52	23.05	

[1] Normal corn (NC) + available phosphorus (aP) at 0.18% NRC (NC NRC Hi), NC + aP at NRC (NC NRC), NC with no added P (NC NRC Lo), DDC + aP at 0.18% NRC (DDC NRC Hi), DDC + aP at NRC (DDC NRC), DDC + P added to equal the tP in NC NRC Lo (DDC NRC Lo).

[2] SEM; P = 0.04; Corn, $P \leq 0.04$

[3] SEM; P = 0.03; NRC, $P \leq 0.03$

[x, y] Means within a parameter lacking a common superscript differ significantly ($P \leq 0.05$).

Table 5.7. Torsion (MPa), Bone Mineral Density (g/cm^2), and Bone Mineral Content (g) measured of male turkeys at 20 weeks of age fed 6 dietary treatments[1].

	Maximum Sheer Stress (MPa)[2]			Bone Mineral Density (g/cm^2)[3]			Bone Mineral Content (g)[4]		
aP Level	NC	DDC	$\bar{x}$	NC	DDC	$\bar{x}$	NC	DDC	$\bar{x}$
NRC Hi[5]	38.65	32.63	35.64	0.41	0.44	0.43^x	14.99	15.52	15.26^x
NRC	31.80	37.59	34.69	0.43	0.44	0.43^x	15.74	15.39	15.57^x
NRC Lo	40.87	41.04	40.95	0.39	0.41	0.40^y	13.62	14.27	13.95^y
$\bar{x}$[6]	37.11	37.09		0.41^y	0.43^x		14.78	15.06	

[1] Normal corn (NC) + available phosphorus (aP) at 0.18% NRC (NC NRC Hi), NC + aP at NRC (NC NRC), NC with no added P (NC NRC Lo), DDC + aP at 0.18% NRC (DDC NRC Hi), DDC + aP at NRC (DDC NRC), DDC + P added to equal the tP in NC NRC Lo (DDC NRC Lo).

[2] SEM = 3.00

[3] SEM = 0.01; Corn, $P \leq 0.03$; NRC, $P \leq 0.02$

[4] SEM = 0.44; NRC, $P \leq 0.002$

[x, y] Means within a parameter lacking a common superscript differ significantly ($P \leq 0.05$).

Table 5.8. Total phosphorus (P) consumed (kg), whole body P (kg), and the difference (kg) between consumed P and whole body P measured of male turkeys raised from 12 to 20 weeks of age fed 6 dietary treatments[1] based on total P analysis.

	P Consumed (kg)[2]			Whole Body P (kg)[3]			Difference (kg)[4]		
aP Level	NC	DDC	$\bar{x}$	NC	DDC	$\bar{x}$	NC	DDC	$\bar{x}$
NRC Hi	0.50	0.47	0.48	0.12	0.17	0.15	0.38	0.31	0.35
NRC	0.52	0.51	0.52	0.13	0.15	0.14	0.39	0.37	0.38
NRC Lo	0.48	0.48	0.48	0.11	0.15	0.13	0.37	0.33	0.35
$\bar{x}$	0.50	0.48		0.12^{y}	0.15^{x}		0.38	0.34	

[1] Normal corn (NC) + available phosphorus (aP) at 0.18% NRC (NC NRC Hi), NC + aP at NRC (NC NRC), NC with no added P (NC NRC Lo), DDC + aP at 0.18% NRC (DDC NRC Hi), DDC + aP at NRC (DDC NRC), DDC + P added to equal the tP in NC NRC Lo (DDC NRC Lo).

[2] SEM = 0.030

[3] SEM = 0.017; Corn, P = 0.01

[4] SEM = 0.040

[x, y] Means within a parameter lacking a common superscript differ significantly ($P \leq 0.05$).

Table 5.9. AMEn (kcal/kg) and ANR (%) measured of male turkeys raised from 12 to 20 weeks of age fed 6 dietary treatments[1].

Treatment	AME (kcal/kg)[2]	ANR (%)[3]
NC	1719.0	73.66[a]
DDC	1677.2	59.99[b]
P-value		0.008
NRC Hi	1749.3	67.05
NRC	1625.0	60.57
NRC Lo	1720.1	72.86
SEM	123.2	5.24

[1] Normal corn (NC) + available phosphorus (aP) at 0.18% NRC (NC NRC Hi), NC + aP at NRC (NC NRC), NC with no added P (NC NRC Lo), DDC + aP at 0.18% NRC (DDC NRC Hi), DDC + aP at NRC (DDC NRC), DDC + P added to equal the tP in NC NRC Lo (DDC NRC Lo).

[2] SEM

[3] SEM

[a, b] At 20 weeks of age there was a corn source effect ($P \leq 0.008$). Turkeys fed NC had a higher ANR (%) than turkeys fed DDC.

Table 5.10. Fecal phosphorus (%) measured of male turkeys raised from 12 to 20 weeks of age fed 6 dietary treatments[1].

	Fecal P (%)[2]		
aP Level	NC	DDC	$\bar{x}$
NRC Hi	3.42[a]	1.87[b]	2.64[x]
NRC	1.10[c]	1.29[c]	1.20[y]
NRC Lo	0.70[d]	1.00[cd]	0.85[y]
$\bar{x}$	1.73[x]	1.39[y]	

[1] Normal corn (NC) + available phosphorus (aP) at 0.18% NRC (NC NRC Hi), NC + aP at NRC (NC NRC), NC with no added P (NC NRC Lo), DDC + aP at 0.18% NRC (DDC NRC Hi), DDC + aP at NRC (DDC NRC), DDC + P added to equal the tP in NC NRC Lo (DDC NRC Lo).

[2] SEM = 0.21; Corn, P = 0.02; NRC, P = 0.001; Corn X NRC level, P = 0.0001

[a-d] Means lacking a common superscript differ significantly ($P \leq 0.05$).

[x, y] Means within a mean lacking a common superscript differ significantly ($P \leq 0.05$).

APPENDIX

Appendix I: Phosphorus Assay

Microtiter Plate Protocol
(tibia, fecal, water-soluble fecal P, yolk, albumen, serum/plasma)

This assay is used to measure P content using a Microtiter plate reader. Past methods of measuring P were time consuming and required materials such as chemicals and lab equipment on a larger scale. This assay was developed in order to decrease the time and the amount of materials needed to perform the assay.

A. All samples (except blood) must be ashed in the muffle furnace. The crucibles used must be acid washed to avoid phosphorus contamination. See section D. to run blood (serum/plasma samples.)

B. Reagents:

1. Molybdate Reagent:
   [chemicals: ammonium Molybdate and sulfuric acid (H_2SO_4)]
   - a Into a clean, acid washed 500ml vol. flask, add 200ml distilled H_2O; set in an ice bath
   - b. Slowly, with cooling add 45mo conc. H_2SO_4
   - c. Dissolve 22g Ammonium Molybdate in an acid washed beaker containing 200ml distilled H_2O
   - d. Pour Ammonium Molybdate solution into H_2SO_4 solution; mix; let stand until completely cooled-bring to the 500ml mark; mix
   - e. <u>Store in a brown bottle</u> (stable for several years)

2. Iron-TCA Reagent:
   [chemicals: Trichloroacetic Acid (TCA), ferrous ammonium sulfate, and thiourea]
   - a Into a clean, acid washed, 1000ml flask dissolve the following:
     1. 125g TCA
     2. 37.5g Ferrous Ammonium Sulfate
     3. 12.5g Thiourea
     4. <u>Store in a brown bottle</u> (stable for 6-12 months)

NOTE: A precipitate of sulfur will form after several days. <u>FILTER</u> before using.

C. Phosphorus Standard
(use same standards for all samples)
Use standards in 0-20% range for accuracy
Dry 0.0878g of KH_2PO_4 (1 hour)
Place in 100ml of dH_2O

Phosphorus Standard Curve:

Percent (%)	Stock (ml)	dH_2O (ml)
20	10	0
18	9	1
16	8	2
14	7	3
12	6	4
10	5	5
8	4	6
6	3	7
4	2	8
2	1	9
0	0	10

D. Parameters:
1. All samples except serum/plasma, water-soluble fecal P
   a. Weigh
   b. Dry (oven at 65-100 ºC)
   c. Weigh (fecal and tibia must be ground before next step)
   d. Ash in muffle furnace at 600 ºC (1g sample)
   e. Weigh
   f. Digest with HCL
      1. Albumen 1.5 H_2O and 0.5 HCL
      2. Yolk* 1.5 H_2O and 0.5 HCL
      3. Bone* 1.5 H_2O and 0.5 HCL
      4. Fecal* 1.5 H_2O and 0.5 HCL
      5. Whole Body P* 1.5 H_2O and 0.5 HCL

* Samples are too concentrated and need to be serial diluted in order to use 0-20% standards; Or create a standard curve from 0-100%

- Yolk is a 10 fold dilution
- Bone (tibia) is a 100 fold dilution
- Fecal is a 100 fold dilution
- Whole Body P is a 50 fold dilution

2. Water-Soluble Fecal P:
   a. Follow steps 1-3 (Section C.)
   b. In a centrifuge tube place 1g sample
   c. Ass 20ml dH2O
   d. Shake for 1 hour
   e. Centrifuge at 2200rpm for 30 minutes
   f. Filter through 0.45 millapore filter paper
   g. This solution will be sued in the assay as follows in Section D.

3. Units
   a. Albumen P (mg %)
   b. Yolk P (mg %)
   c. Tibia P (%)
   d. Fecal P (%)
   e. Plasma P (mg %)
   f. Water-soluble fecal P (mg % extracted Soluble Reactive Phosphorus)
   g. Whole Body P (%)

E. Running the Assay:
1. Run samples in triplicate
2. Place blank into the first three wells in column1:
   a. 240 µl TCA
   b. 10 µl dH_20
   c. 25 µl molybdate
3. Place standards* into the first three wells of columns 2-6 respectively:
   a. 240 µl TCA
   b. 10 µl standard (values)
   c. 25 µl molybdate
4. Place samples into the first three wells of columns remaining:
   a. 240 µl TCA
   b. 10 µl sample
   c. 25 µl molybdate

5. Follow the procedure for the Softmax program and setting up the Microplate Reader.
6. Then read plate.

* The use of the standards should produce a straight line. First test all standards to identify if the concentration is correct. Next use at least five points to perform assay.

F. Serum/Plasma Phosphorus

[A protein-free filtrate must be prepared from the serum or plasma:]

1. 0.2ml serum/plasma in small plastic tube (ullet tube)
2. Add 0.8ml 5% TCA
3. Mix on vortex-let stand for 15-20 minutes
4. Spin
5. Pour off the clear supernatant into another bullet tube
6. Use 0.1ml of this filtrate

G. Chemicals

Chemical	Company *	Chem. No.	Amt
Ammonium Molybdate	S	A-7302	100g
Sulfuric Acid	F	A-300-500	500ml
Trichloroacetic Acid (TCA)	F	A-322-500	500g
Ferrous Ammonium Sulfate	S	F-1543	500g
Thiourea	F	T-101-100	100g

Bones

Chemical	Company *	Chem. No.	Amt
Chloroform	F	C-295-4	4L

* S Scientific
F Fisher

SUMMARY AND CONCLUSION

The objective of this research was to evaluate the efficacy of using alternative feed ingredients as a means to reduce fecal phosphorus (P) excretion without impairing growth performance. Poultry diets are primarily composed of seed based feed ingredients. Approximately two-thirds of the P in these ingredients is present as phytate which is poorly available to poultry (NRC, 1994; Angel et al., 2002). This results in the need to add inorganic sources of P such as dicalcium phosphate to satisfy the birds' dietary requirements. It is the addition of inorganic P in surplus of the birds' dietary needs and the undigested phytate P that results in excess fecal P excretion.

This study examined alternative seed based ingredients such as mechanical modified corn and genetically modified soybean meal (SBM) in order to reduce P excretion. In corn, approximately 90% of phytate P is located within the germ portion of the seed (Oberleas and Harland, 1996). Degermed-dehulled corn (DDC) is a mechanically altered corn product that contains reduced phytate P. Turkeys fed a diet with DDC as the primary grain source rather than normal corn perfromed equal to turkeys fed normal corn from day of hatch to 20 weeks of age.

Soybean meal is commonly added to poultry diets as a source of protein. In SBM, approximately 55 to 60% of the total P is bound to phytate (Ravindran et al., 1995). Genetically modified low-phytate soybean meal (LP SBM) as been selected to contain more available P when compared to conventional varieties (Raboy, 2002). Turkeys fed a diet with LP SBM rather than SBM resulted in performance equal to turkeys fed normal SBM from day of hatch to 18 days of age. The combination of DDC and LP SBM in replacement for normal corn and SBM resulted in further reduction of fecal P.

In addition to examining DDC (and LP SBM) differing levels of Ca and P NRC recommendations were fed to turkeys to various ages to determine if performance could be maintained while reducing fecal P excretion. It was found that Ca and P dietary requirements for growth, feed conversion, and bone health could be met feeding 100% of recommended NRC values while also resulting in decreased P excretion.

In conclusion, this series of experiments provides evidence that feeding DDC and LP SBM do not affect growth parameters; however, it can provide the opportunity to reduce turkey P excretion. Feeding DDC, in combination with other nutritional practices such as also feeding LP SBM, could reduce turkey P excretion and, thereby reducing P accumulation in environmentally sensitive water sheds located in turkey producing regions.