CONTINUOUS MULTI-PHASE FEEDING OF BROILER CHICKENS

A Dissertation

by

NASRIL

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

December 2003

Major Subject: Poultry Science

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ABSTRACT

Continuous Multi-Phase Feeding of Broiler Chickens. (December 2003)

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Continuous multi-phase feeding of broiler chickens was evaluated to optimize broiler nutrition and minimize environmental impact related to excess nitrogen in poultry manure. Four experiments were conducted. Experiments 1 and 2 studied effects of continuous multi-phase feeding during a 3-week starting period using battery brooders while experiments 3 and 4 evaluated multi-phase feeding during a traditional 7-week growing period using both battery brooders and floor pens.

In the first and second experiments, the nutrient content of the multi-phase diets was changed every 24 hours in comparison to single-phase feeding. Results indicated that during the starter period, continuous multi-phase feeding had no significant influence on feed consumption, daily gain, feed to gain ratio or fecal nitrogen.

In the third and fourth experiments, a four phase industry type broiler feeding program was compared to intensive multi-phase feeding programs created by linearly blending three different diets based on typical industry nutrient values and a commercial nutrient modeling computer program (EFG Natal®). In both intensive multi-phase feeding programs, the diets were changed every three days over a 7-week growth period. Broilers in experiment 3 were raised in Petersime battery brooders to primarily access nitrogen balance while birds in experiment 4 were raised in a floor pen on pine shaving litter to resemble commercial broiler production. The results indicated that intensive multi-phase feeding improved body weight gain and feed to gain ratio only in weeks 5 and 6 but not during the overall 7-week period. Nitrogen excretion and nitrogen retention were unaffected by the intensive multi-phase feeding systems. Economic analysis indicated that intensive multi-phase feeding programs could potentially lower feed costs per kilogram of gain. However, the high cost of implementing a continuous multi-phase feeding system may not justify the relatively small gain in lower feed cost per kilogram of gain. In conclusion, continuous multi-phase feeding of broiler chickens using corn-soy diets does not appear to be justified by either increased performance or reduced nitrogen excretion.

DEDICATION

To my wife Evelyn Sriwanti, my daughter Rachel Monica and my son Nicholas Nehemia…you are the love of my life.

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CHAPTER I

INTRODUCTION

During the past several decades, poultry production units have increased consistently in size. USDA-NASS Agricultural Statistics (2002) indicates that approximately 9 billion broilers were produced in the USA in 2002. As production unit size increases, so does the volume of manure produced. According to these numbers, about 30 billion kilograms of manure will be produced annually resulting in 1.2 billion kilograms of nitrogen. The large amount of manure from poultry production can become a hazard to the environment as well as a detriment to the health and safety of both humans and animals.

The high solubility of poultry manure in water makes it a potential contributor to water pollution. The application of excessive amounts of poultry manure can result in the leaching of nutrients through the soil and into the local groundwater. According to limited data compiled by the EPA, agricultural production is the leading source of water quality impairments in United States rivers and lakes (Copeland and Zinn, 1998).

The dominant form of inorganic N in manure is ammonium (NH_4^+). As pH increases, ammonium is converted to ammonia which diffuses from the litter into the atmosphere. Ammonia volatilization can lead to very high levels of ammonia in poultry houses, as well as cause atmospheric ammonia pollution. Chronic exposure to ammonia can cause serious health problems in humans (U.S. EPA, 1981). Another concern from

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This dissertation follows the style and format of Poultry Science.

atmospheric ammonia pollution is acid rain. Van Breemen et al. (1982) found that when ammonia is absorbed into rainwater, it initially increases the pH. This increase in pH increases the amount of SO_2 that will dissolve in water. Ammonium sulfate can then be formed and when rain water reaches the soil, the ammonium is oxidized to nitrate by microorganisms, releasing both nitric and sulfuric acid.

Gillham and Webber (1969) studied nitrate contamination of groundwater under a manure storage pile site on a loam soil. They observed a plume of contamination skewed toward the direction of groundwater flow. Nitrate concentrations were greater than 15 mg/L close to the pile, and greater than 5 mg/L 90 m distant in the direction of flow. The application of poultry manure to pasture has often increased the groundwater nitrate concentrations to higher levels than application of commercial fertilizers. Water pollution by poultry manure can result in several dire consequences. The oxygen level in the water is depleted because bacteria decomposing the manure constituents demand oxygen for the process. If dissolved oxygen concentrations are seriously depleted, the water may no longer support desirable aquatic life such as fish, but instead become septic and unpleasant. The pollution of water resulting from poultry manure can also present a health hazard to both humans and livestock. The pollution of water by poultry manure may be responsible for nitrate poisoning and potentially leading to infant cyanosis (Livestock Waste Facilities Handbook, 1993).

In their literature review, William (2001) proposed some basic strategies to reduce environmental pollution caused by livestock production: (1) reduce excess nitrogen and phosphate in the feed; (2) implement practical farm level solutions such as distribution and application of manure to nutrient deficient areas; (3) upgrade manure management by processing and coupling with a large-scale export scheme; and (4) improve the efficiency of nutrient use by animals. Among these strategies, improving efficiency of nutrient use is the most feasible approach to minimize nutrient emission problems in most geographical areas (Ferket et al., 2002). Improving nutrient efficiency can be achieved by using precision nutrition.

Precision nutrition is defined as providing the animal with the feed that precisely meets its nutritional requirements at any given time (Sifri, 1997). However, precision nutrition is difficult to accomplish because it is difficult to know precise nutrient requirements at specific times in an animal's life. According to Ferket et al. (2002) nutrient requirements are moving targets that are influenced by many factors and changed by the genetic characteristics of the animal in question. Tremendous genetic progress has been made by the poultry industry over the last century. As a consequence, there is considerable genetic variation in growth characteristics of animals, particularly with respect to the retention of protein. Thus each strain will have its own specific rate of protein deposition and optimal dietary protein requirements in the diet (Verstegen and Tamminga, 2002). Moreover, nutritional requirements of poultry (NRC, 1994) have been defined under laboratory-type conditions where animals are well cared for and the environmental conditions are maintained as close as possible to optimum. As a consequence, stated National Research Council requirements will be different than field production requirements. Because the typical formulation model for poultry feed used today simply calculates the combination of ingredients that meet given specifications at the least cost (Pesti and Miller, 1997) diets often contain an excess of some nutrients. Finally, feedstuffs are derived from multiple sources and may exhibit large variations in nutritional value. For example, Roush (2002) reported coefficients of variation for digestible lysine and methionine of a feed containing 65% corn, 25% soybean meal, and 5% poultry by product at 8.7 and 9.2% respectively. As a result, every batch of feed will have a different nutrient content. Variability of ingredient nutrients can push nutritionists to apply a margin of safety to meet the bird requirements which can lead to even greater nutrient loss from imprecise formulation.

According to Morse (1995), the excretion of N originating from dietary protein is largely responsible for the negative impact of nitrogen excretion from intensive livestock production. There is a strong correlation between dietary protein intake and nitrogen excretion. From the nutritional standpoint, the easiest way to reduce nitrogen excretion is to use low-protein diets. Kerr and Easter (1995) calculated that for each percentage point decrease in the dietary crude protein (with the use of crystalline amino acids) the amount of excreted N was reduced by 8% in pigs. However, several experiments with broiler chicks showed that growth performance and carcass composition become inferior to those of broiler chicks fed standard high crude protein diets when the dietary CP content is lowered by more than three to four percent (Ferguson et al, 1998).

Feeding programs for today's broiler may utilize three or four different diets. The NRC (1994) provides requirements for three fixed periods: starter, 0 to 3 weeks of age; grower, 3 to 6 weeks of age; and finisher, 6 to 8 weeks of age. Requirements for most nutrients decrease with the age of the broiler. If a single diet is used, broilers are either under- or over-supplied with nutrients for most of the growth period.

Multi-phase feeding is designed to meet the bird's nutritional needs at several points in the life cycle. Changing the diet multiple times in the course of the broiler's life in order to better match nutritional requirements to the specific nutritional need will usually improve feed efficiency. Multi-phase feeding has been used in swine to decrease nitrogen excretion without sacrificing growth performance; nitrogen excretion was reduced significantly during the early growing period (Kim et al., 2000). The other advantage of multi-phase feeding is reduced diet cost (Pope and Emmert, 2001), although they did not discuss the total operational cost.

Multi-phase feeding of broilers does not always result in improved performance. Warren and Emmert (2000) broke up the traditional broiler starter period into three weekly phases (0 to 7, 7 to 14 and 14 to 21 days) and reported no significant differences in weight gain, feed intake, and feed efficiency. Pope et al. (2002) studied phase feeding in broilers with diets switched every other day from 42 to 60 days of age, and found no difference in weight gain, feed intake, feed efficiency and carcass composition. However, the cost of production was reduced. A strategy to match feed composition to the broiler's nutritional requirements daily throughout the growth period is called "continuous multi-phase feeding." To do this economically, starter and grower/finisher feeds are blended together daily at the rearing facility as the feed is being delivered directly to the chickens. Two feed bins and a proportioning system are required at each chicken house. Luckily, the majority of poultry houses in the U.S. are already equipped with two exterior feed bins. Recently, Flockman™[1], a company based in England, has offered technology to blend a cereal grain with a concentrate diet at the production facility using a computer control system. One of the problems with this approach is that the amino acid profile changes towards that of the grain as more and more grain is blended. Flockman™ systems have been used successfully in Europe but is not prevalent in the United States.

There is little to no data in the literature with respect to continuous multi-phase feeding. Research proposed herein will address continuous multi-phase feeding of broiler chickens with respect to combined effects on performance, nitrogen retention and excretion. Both battery brooder and floor pen studies were conducted using nutrient requirements typical of the commercial industry (Agri Stats data, for February 2001) and requirements predicted using broiler growth modeling software (EFG Natal®[2]). The modeling software is based on the Gompertz equation and takes both environmental and breed effects into account.

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[1]Flockman™, Somerset, England.
[2]EFG Natal®, Pietermaritzburg, South Africa.

CHAPTER II

LITERATURE REVIEW

Protein Metabolism

Proteins are compounds composed of carbon, hydrogen, oxygen, nitrogen and in some cases, sulfur. In general, protein contains an average of 16% nitrogen. According to Voet et al. (1999) proteins play a role in all biological processes because essentially all molecular transformations that define cellular metabolism are mediated by protein catalysts, or enzymes. Dietary protein supply is one of the major factors influencing the productivity of farm animals. Proteins are long chains of up to 22 amino acids that have been linked together by peptide bonds. Amino acids are compounds that contain both an amino (-NH2) and a carboxy (COOH) group attached to a carbon skeleton. The physical and chemical characteristics of proteins are derived from their amino acid sequence and the subsequent linkages formed between the different amino acids and other compounds. The production of proteins is regulated by the genetic material or DNA contained in the nucleus of the animal's cells. Many factors are known to determine the rate of protein or polypeptide elongation on the ribosomes (Buttery and D'Mello, 1994). According to Houlihan et al. (1995) polypeptide synthesis proceeds through three stages; (1) the formation of the initiation complex that contains two ribosomal subunits; (2) the process of peptide chain elongation and; (3) the process of termination.

In the growing animal there is a balance between protein synthesis and protein degradation. Amino acid catabolism and protein synthesis would appear to be linked processes. According to Buttery and D'Mello (1994) when the supply of an amino acid is low it is used relatively efficient enough for protein synthesis, but as the supply of amino acid is in excess of that required for protein synthesis amino acid oxidation increases. This mechanism ensures that when amino acids are in short supply they are preferentially used for body protein synthesis. The increase in amino acid oxidation as amino acid supply exceeds the requirements for protein anabolism has often been used to assess the requirement of an animal for individual amino acids. Kim et al. (1983) were able to determine the methionine requirement of pigs using ^{14}C-phenylalanine as an indicator amino acid. At dietary methionine concentrations below those required for maintenance, body protein is degraded to supplement the deficient amino acid supply and other amino acids, such as phenylalanine are in excess. As the methionine supply increases, protein anabolism increases, and the excess of serum phenylalanine is reduced and thus phenylalanine oxidation is reduced.

The efficiency of dietary nitrogen utilization varies depending upon the species, and it is dependent upon the degree of protein N digestibility, amino acid N absorption or availability, metabolic N demands, and dietary amino acid imbalance. Poultry are most efficient at utilizing dietary nitrogen in the form of protein, followed by swine and cattle (Verstegen, 1995). Moreover, he reported ratios of retained nitrogen to N content in diets for cattle, pigs and poultry were 0.15, 0.29 and 0.31. These differences in N utilization among the species are partly due to the partitioning of nitrogen utilized for maintenance, metabolism and growth. The efficiency of nitrogen utilization decreases as maintenance requirements for nitrogen increases; and the larger the body size, the greater the maintenance requirement for nitrogen (Ferket, 1999). Moreover, dietary N utilization in ruminants is low because of the complexities of fermentation by rumen microflora.

Dietary protein is the predominant form of N entering the body. Digestion of protein begins in the stomach by the combined action of gastric secretions of hydrochloric acid and pepsin and is completed in the small intestines by pancreatic proteases, such as trypsin and chymotrypsin, and by brush border peptidases. Protein metabolism in non-ruminants is illustrated in Figure 2-1 (Ferket et al., 2002).

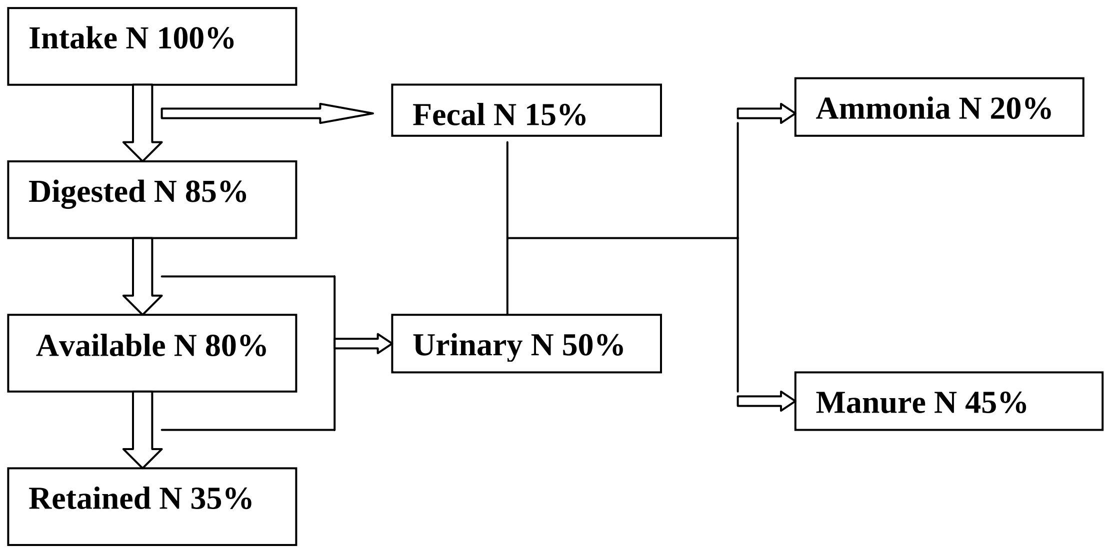

FIGURE 2-1. Nitrogen flow in poultry and swine. (Ferket et al., 2002).

Protein Requirements

The dietary requirement for poultry is for essential amino acids rather than protein *per se*. Amino acids are required for maintenance of protein in body tissues and for protein deposition in the carcass and other body tissues. In amino acid nutrition, maintenance refers to a state in which protein is not being deposited for growth, reproduction or feather replacement (Larbier, 1987; D'Mello, 1994). Maintenance amino acid requirements are due to obligatory losses and are low relative to those needed by growing birds. According to Classen and Stevens (1995) the balance of amino acids needed for maintenance is not proportional to the balance of amino acids in the tissue, but rather reflects the relative rate of obligatory loss of each individual amino acid. Methionine, arginine, and threonine are required at proportionally high levels. Dietary amino acid levels slightly below maintenance can sustain life, but muscle mass and function are impaired (Han and Baker, 1993). The balance of amino acids required for growth closely reflects the pattern of amino acids incorporated into tissue proteins. This is because needs for protein accretion are considerably greater than needs for maintenance. For example, in young growing chickens, 94% of the valine requirement is used to support growth and only 6% is required to replace obligatory losses (Baker et al., 1994). Fractional rate of growth (% increase/day) of chicks is highest after hatching and decreases steadily until an adult lean body mass is achieved. According to Han and Baker (1991) the requirement at any given age varies directly with a bird's fractional growth rate. Thus, the amino acid requirements (% of the diet) decrease with age and, at the same time, the ideal balance of amino acids changes gradually to reflect those of maintenance.

Birds laying eggs need dietary amino acids for normal maintenance, growth of the oviduct, and accretion of egg proteins. The growth of the oviduct and the synthesis of several yolks are mostly complete before the first egg is laid. Consequently, the female's requirement increases at least a week prior to her first oviposition. In most species, egg albumen is synthesized in the oviduct during a 24-hour period before ovulation (Fisher, 1994). Thus, dietary amino acid requirements are especially high on the day preceding each oviposition. Energy requirements also increase during egg production, in order to deposit lipid in the yolk and to synthesize protein and other egg nutrients. Because the requirement of energy does not increase as much as that for amino acids, higher concentrations of dietary protein are needed relative to energy during periods of high egg production (Fisher, 1994).

Amino acid requirements are based on many aspects of poultry nutrition. For example, dietary metabolizable energy has an important impact on feed intake, therefore amino acid requirements change as the dietary metabolizable energy changes. Although National Research Council (NRC) recommendations are available for poultry nutrient requirements (NRC, 1994), some specifications are based on out-of-date research publications and others are just estimates.

Amino acid requirements can be predicted using mathematical models. According to Black and De Lange (1995), at least the following information is needed: (1) body composition, (2) nutrient intake, (3) availability of the dietary nutrients, (4) maintenance requirements and growth requirements. Many attempts have been made to express the growth of animals in mathematical terms. Although varying in specific details, these models all have a sigmoid form. The Gompertz function is probably the best to describe broiler chicken growth (Shalev, 1995). The chemical and physical composition of the body changes systematically during growth, so a single growth function may not be sufficient to describe the changes in composition as growth proceeds. The Emmans model (1987) includes terms for lean tissue growth, allowing estimation of the yield of carcass parts. Recently, another commercial software package (EFG Broiler Growth Model 5.1, 2002) integrates information about genotype, environment, feed and feeding programs, including controlled feeding. This computer program is named after G.C. Emmans, Colin Fisher and Rob Gous, well-known nutritionist, who have developed the model. The model also provides information about potential growth rate and carcass composition of broilers and can be used to determine amino acid requirements on each day of the growing period. Although these computer models can be very useful for estimating requirements, data validating them under commercial production are limited and changes in genetics means they are in constant flux.

Nitrogen Excretion

Unlike carbohydrates and lipids, excess dietary protein can not be stored as a readily available source of labile amino acids. The nitrogen of degraded amino acids is incorporated into uric acid while the carbon skeleton can be used for: (1) glucose synthesis; (2) fat synthesis or; or (3) degraded directly to CO2 + H2O and energy. Some amino acid degradation occurs constantly and there is a linear relationship between crude protein in the diet and the quantity of amino acids degraded (Leeson and Summer, 2001).

According to Campbell (1995) terrestrial vertebrates use two mechanisms for detoxication of ammonia generated during hepatic amino acid catabolism: (1) its conversion to urea for excretion (ureoteley) and (2) its conversion to uric acid (uricoteley). In both mechanisms, the primary ammonia-detoxyfying reaction is located within the mitochondrial matrix of liver cells. The end products of nitrogen metabolism excreted in the urine of birds include urates, ammonia, urea, and small amount of creatinine, amino acids and purines. Of these, urates are the prodominant compounds under all circumstances, though ammonia may account for as much as 25% of total nitrogen (Goldstein and Skadhauge, 2000).

In birds, there is increased urate excretion with increased dietary protein intake (McNabb and McNabb, 1975), so long term adaptation of the urate pathway probably involves some sort of concerted increase in the level of enzymes of the pathway as in the urea pathway. The response to increased dietary protein intake is the most straight forward. Under these conditions, there is a very marked increase in alanine amino transferase which in chicken liver, is exclusively mitochondrial (Campbell, 1995).

Composition of Broiler Manure

Poultry produce about as many pounds of manure (as is basis) as pounds of feed consumed. The large amount of manure from poultry production can become a hazard to the environment as well as a detriment to the health and safety of both humans and animals.

Litter or floor systems are used mostly for broiler production. An absorbent litter material is usually laid down on the floor depending on the needed absorption and commercial availability (Collins et al., 1999). The removal of this litter is handled in solid form and can be done after each brood, yearly, or can be left for longer periods to add more litter and produce a “deep littering“ system.

The chemical composition of poultry manure has been extensively analyzed in the past 30 years or so. According to Collins et al. (1999) chemical composition of poultry manure will vary because of several factors: species, age, diet and nutrition, bird productivity, management, housing, ventilation, drinker systems and environmental factors.

Farm animals consume considerable amounts of protein and other nitrogen-containing substances in their feed and a large proportion of nitrogen is lost in the feces and urine. Nitrogen excreted in feces originates from the feed and from endogenous sources such as sloughed cells. In poultry, feces and urine are mixed, and most of the nitrogen in the urine is the form of uric acid. According to Chescheir et al. (1986), dry poultry manure contains 4-14% N, of which 49-62% is ammonia. The total N content of manure at any given time is difficult to predict because of volatilization losses as ammonia. Burton and Beauchamp (1986) reported volatilization losses from three swine barns in Ontario ranged from 5 to 27% of the total manure N, and varied greatly between management systems.

The Association of American Feed Control Officials (AAFCO, 2001) defines dry poultry waste as freshly collected feces from commercial laying or broiler flock not receiving medicaments and thermally dehydrated to a moisture content of not more than 15%.

Manure production and the chemical composition of several poultry wastes are shown in Tables 2-1 and 2-2 (Collins et al., 1999).

TABLE 2-1. Manure production, as excreted (Collins et al., 1999)

Bird type	Live weight (lbs)		Total manure production/1000 birds/day		
	Market	Average	(lbs)	(ft^3)	(gallons)
Commercial layer					
Hen	4.0	4.0	260	4.2	32
Pullet	3.0	1.5	97	1.6	12
Turkey					
Poult	5.0	2.5	113	1.8	13
Grower hen	16.0	10.0	452	7.1	53
Grower tom, light	22.0	13.0	588	9.3	69
Grower tom, heavy	30.0	17.0	769	12.1	91
Breeder	20.0	20.0	905	14.3	107
Broiler	4.5	2.25	177	2.8	21
Roaster	8.0	4.0	315	4.9	37
Cornish	2.5	1.25	99	1.5	12
Breeder	7.0	7.0	552	8.7	65
Duck	6.0	3.0	328	5.3	39

Note: Total manure production is presented per 1,000 bird capacity per day based on the weighed average daily live weight of the birds during their production cycle.

TABLE 2-2. Manure characteristics, as excreted (Collins et al., 1999)

Manure characteristics	Layer	Broiler	Turkey	Duck
Density (lbs/ft^3)	62	64	63	62
TS (%)	25	26	25	27
VS (%)	19	19	19	16
COD (ppm)	176,000	197,000	236,000	169,000
Total N (lbs/ton)	27	26	28	28
NH3 N (lbs/ton)	6.6	6.7	8.1	7.4
P2O5 (lbs/ton)	21	16	24	23
K2O (lbs/ton)	12	12	12	17
Ca (lbs/ton)	41	10	27	29
Mg (lbs/ton)	4.3	3.5	3.1	4.1
S (lbs/ton)	4.3	2.0	3.3	3.6
Na (lbs/ton)	3.6	3.5	2.8	3.5
Cl (lbs/ton)	20	18	18	20
Fe (lbs/ton)	2.0	1.9	3.2	2.8
Mn (lbs/ton)	0.16	0.20	0.10	0.17
B (lbs/ton)	0.05	0.06	0.06	0.06
Zn (lbs/ton)	0.14	0.084	0.62	0.48
Cu (lbs/ton)	0.02	0.02	0.03	0.03

Note: TS = Total solids, VS = volatile solids, COD = chemical oxygen demand.

Environmental and Public Health Concerns Regarding Broiler Manure

According to limited data submitted by states and compiled by the EPA, agriculture is the leading source of water quality impairments in U.S. rivers and lakes, affecting 60% of impaired river miles and 50% of impaired lake acres (Copeland and Zinn, 1998). With respect to animal production, ruminant species emit the greatest amount of N into the environment (71%) with production primarily concentrated in Texas, Nebraska, Kansas, and Iowa. Poultry and swine production result in another 20% and 9% respectively, North Carolina, Arkansas, Alabama, Mississippi and Georgia are particular problem areas (Ferket et al., 2002).

The manure resulting from poultry production can become a hazard to the environment as well as a detriment to the health and safety of both humans and animals. The high solubility of poultry manure in water increases the risk of water pollution. The application of excessive amounts of poultry manure can result in the leaching of nutrients through the soil and into the local groundwater. According to Copeland and Zinn (1998) the land application of poultry manure can sometimes increase local ground water nitrate concentrations to higher levels than that from application of some commercial fertilizers. Poultry manure nitrates and phosphates may cause or contribute to unsightly algae blooms, impaired fisheries, fish kills, unpleasant odors and increased turbidity.

Water pollution by poultry manure can result in several consequences. The oxygen level in the water is depleted because bacteria decomposing the manure demand oxygen for the process. If dissolved oxygen concentrations are seriously depleted, the water may no longer support desirable aquatic life such as fish, but instead become septic and unpleasant. The pollution of water resulting from poultry manure can also present a health hazard to both humans and livestock, and the pollution of water by poultry manure may be responsible for nitrate poisoning in both animals and humans, particularly infants (Owen, 1994).

After being excreted, broiler manure is converted by largely anaerobic microbial activity into microbial biomass and water soluble or gaseous waste products. For cattle and pigs, urea in the urine is converted into ammonia as soon as the urine and feces come into contact. However, in poultry the conversion of uric acid, into urea and then on to ammonia takes one or more days (Monteny, 1994).

As a percentage of total nitrogen intake, ammonia emission is lowest for poultry facilities and highest for swine, primarily due to the way the manure is handled and land applied. Poultry broiler manure is usually land applied as a dry litter, whereas most swine manure is treated in an anaerobic lagoon and effluent is land applied by irrigation spray (Ferket, 1999).

Ammonia, dinitrogen oxide, nitrogen oxide, nitrogen dioxide, and a wide variety of noxious odors are produced from animal waste (Verstegen et al., 1994). At high levels, ammonia and other nitrogenous gases may be poisonous. Threshold limit values (TLVs) for humans at a daily subjection time of 8 hours during 5 days are 25, 25, and 5 ppm for ammonia, nitrogen oxide, and nitrogen dioxide respectively (Owen, 1994). Ammonia is detectable by smell at 5-50 ppm, becomes irritating to mucous surfaces at 100-500 ppm causing severe eye irritation, causes coughing and frothing at the mouth with possible fatalities at 2000-3000 ppm, and is rapidly fatal at 10,000 ppm (Bruce, 1981). Until recently, most attention was given to noxious gases from animal waste because of their odor Bundy (1992). Although these odors are non-toxic, they may affect humans by eliciting unpleasant sensations, triggering possible harmful reflexes, modifying olfactory function, and causing other physiological reactions (De Lange, 1997). Unpleasant odors can elicit nausea, vomiting, and headache; causing shallow breathing and coughing; upset sleep, stomach, and appetite; irritate eyes, nose, and throat; disturb, annoy, and depress (Bundy, 1992).

Feeding Strategies for Lowering Nitrogen Excretion

According to De Boer et al. (2000) there are five management strategies feasible for reducing N and P emission related to poultry production: (1) reducing N and P intake (2) improving feed conversion; (3) improving production efficiency; (4) reducing ammonia emission. It has been shown that up to 65% of ingested N is lost in broiler manure (Ferket et al., 2002). Minimizing the quantity of nitrogen in manure should be a goal of animal producers for both economic and environmental reasons. Feeding and nutrition strategies have been most successful in the pig and poultry sectors. Dietary strategies include:

1. Diet formulation based on amino acid requirements rather than crude protein

Dietary formulation based on specific amino acid requirement rather than crude protein (CP) can minimize N excretion by simply reducing total dietary N intake. Ferguson et al. (1998) demonstrated with broilers that litter N could be reduced by 16% when dietary CP was reduce by 2%, while maintaining similar levels of essential dietary amino acids. Since the 1950s, nutritionists have utilized “synthetic” methionine, followed by lysine, and more recently, threonine and tryptophan in poultry diets on cost effective-basis (Waldroup, 1999). Attempts to reduce CP in broiler diets have only been successful to a point. At some reduced level of CP, bird performance suffers even though one has theoretically met all requirements for essential amino acids. For broilers and layers there are biological limits to the amount of dietary protein that can be replaced with synthetic amino acids. Summers et al. (1992) reported impaired weight gain in broilers fed low CP and extra amino acids.

Dietary amino acid requirements for broilers are continually being re-evaluated. The process is complicated by many factors including changing genetic growth characteristics, management factors and physiological status.

2. Optimize the dietary amino acid profile to the bird’s requirements

The closer the amino acid composition of the diet matches the bird’s requirements for maintenance, growth and production of meat and eggs, the fewer amino acids (N) excreted in the feces. Critical amino acids for corn and soybean meal based diets are methionine and lysine. Dietary supplementation of these two amino acids can be used to decrease the diet’s CP content and thereby reduce N excretion. Another approach is to deliver “ideal protein”, whereby the protein portion of the diet precisely meets the bird’s requirements for each amino acid with no excesses or deficiencies. The ideal protein concept was developed by H.H. Mitchell and H.M. Scott at the University of Illinois in the late 1950s and early 1960s. In practice, ideal amino acid ratios are based on lysine as a reference amino acid, with all other essential amino acids expressed as a percentage of lysine. Lysine was chosen as a reference for ideal protein for several reasons (Baker and Han, 1994): (1) dietary lysine is used only for protein accretion and maintenance; (2) in practical broiler diets, lysine is the second-limiting amino acid after methionine plus cystine; (3) lysine supplementation is economically feasible; (4) lysine analysis in feedstuffs is straight-forward; (5) lysine requirement data for a variety of dietary, environmental, body composition and other circumstances are readily available. Baker and Han (1994) have developed the Illinois Ideal Chick Protein (IICP) concept which is based on the ratio of digestible lysine to the requirement for other individual amino acids. Practical implementation of the ideal protein concept is partially restricted by economics and the availability of dietary ingredients with amino acid profiles that more closely match the bird's requirements. Most of the studies establishing ideal ratios of essential amino acids to lysine have been undertaken with chicks between hatching and 21 days post-hatching. In the period from 21 to 42 days ideal ratios to lysine for some amino acids like methionine, threonine and tryptophan have to be higher due to changing maintenance requirements (Peisker, 1999; Boisen et al. 2000). In order to check the efficacy of the IICP, Baker and Han (1994) have compared this profile with the NRC 1984 and 1994 profiles, feeding purified corn-soy diets. Compared to the NRC 1984 requirement, the 1994 NRC estimated lysine requirement was lowered from 12.0 g/kg to 11.0 g/kg of the diet. Estimated requirements for arginine, leucine, cystine, tryptophan and glycine + serine were lowered as well, whereas that for valine was increased. These changes were beneficial, chicks performed markedly better when fed with the NRC 1994 profile than when fed the NRC 1984 profile. The IICP generally uses lower lysine to essential amino acid ratios compared with NRC (1994). Baker and Han (1994) compared the NRC (1994) amino acid profile to the IICP profile with lysine set at only 0.9% of the diet and reported no significant differences in weight gain, feed intake or gain to feed ratio, proving that the lower ratios of the IICP were adequate under the experimental circumstances. Austic (1994) felt that lysine should be set at 13.0 g/kg of the diet, which is higher than the IICP recommendation for males (1.07% digestible). According to Peisker (1999) arginine should be set at 12.5 g/kg. The ratio of lysine to arginine should be approximately 1.25:1 to avoid adverse effects on performance. He felt that threonine should be required at 8.0 g/kg in a 230 g crude protein/kg diet which is similar to the NRC (1994). In addition, tryptophan should be fixed at 11.0 g/kg CP within a CP range from 160-230 g/kg. This corresponds to above 2.4 g of trytophan/kg diet which is higher than the NRC (1994) and most other recommendations found in the literature.

According to Roush (2002) there are other factors that should also be considered with respect to amino acid interactions. For example, the amino acids, cystine and tyrosine, should be considered in ration formulation to lower the total amounts of dietary methionine and phenylalanine. Methionine or phenylalanine can be converted to cystine or tyrosine respectively. However, neither cystine nor tyrosine can be converted to methionine or phenylalanine. Further, cystine may actually be required under certain conditions and may be considered an essential amino acid in its own right, since the bird is not always capable of synthesizing it in adequate amounts (Roush, 2002). Likewise, tryptophan can reduce the need for niacin. Thus, it is prudent to utilize adequate levels of niacin in the diets to reduce the conversion of tryptophan to niacin and to permit the use of tryptophan for tissue synthesis. Similarly, methionine spares the requirement for choline; more choline in the diet is desirable when methionine levels are marginal. In the United States where diets rely heavily on corn and soybean meal, the branched chain amino acid concentrations, such as leucine, are far in excess of the bird's requirements.

3. Formulation strategies

Once nutritional requirements are established, feed must be formulated to assure the appropriate balance of nutrients is provided to the animal. Results of surveys of the nutrient composition of industry diets indicate that they commonly include excess amounts of certain amino acids. These excesses provide a safety margin to compensate for uncertainty about the availability and specific requirements of certain nutrients (Roush, 2002). According to Kornegay and Verstegen (2001) the typical range of industry recommendations was 120 – 130% of the NRC (1994) recommendations. The most obvious way to reduce surplus N-intake is to remove the safety margin. Rapid ingredient analysis techniques at the feed mill, such as near infrared reflectance (NIR), provide nutritionist with data on nutrient variability allowing them to minimize over formulations by reducing margins of safety (Roush, 2002).

The accuracy of feed formulation is dependent upon the following: (1) accurate feedstuff nutrient composition data, (2) minimum feedstuff nutrient variability, and (3) digestibility-based nutrient formulation. Different computer formulation programs will produce diets with different nutrient composition. Zhang and Roush (2002) compared computer feed formulations using traditional linear programming versus a multiple-objective programming model approach. They found the multiple-objective programming model gave the best compromise solution between the ration cost and minimum variances of protein and methionine.

4. Enhancement of protein digestibility through feed processing

Nutrients in feedstuffs have different degrees of availability, depending upon their digestibility. Grinding of ingredients is a traditional part of feed manufacture using hammer mills or roller mills. Fine grinding can improve feed use and decrease dry matter and nutrient excretion. By reducing the particle size, the surface area of the feed ingredient particles is increased, allowing for greater interactions with digestive enzymes.

Essentially all feeds used by the broiler industry are pelleted. The pelleting process is defined as the agglomeration (process of molding into a mass) of small particles into larger particles by the means of a mechanical process in combination with moisture, heat and pressure (Thomas et al., 1997). The pelleting process increases the bulk density and reduces the segregation and dustiness of the feed, thus reducing the losses during handling, transportation, and storage. Moreover, heat treatment (steam conditioning, annular-gap expansion, pellet die extrusion) associated with the pelleting process improves feed digestibility by deactivating anti-nutritional factors and increasing starch gelatinization (Plavnik and Sklan). Pelleting can improve efficiency by 8.5% in pigs and poultry while also improving protein digestibility by 3.7% (Beyer et al., 2001).

Other feed processing methods used to improve nutrient quality include the use of extruders and expanders. Extrusion is the operation of shaping a plastic or dough-like

material by forcing it through a restriction or die (Riaz, 2000). During extrusion, the raw material is subjected to intense mechanical shearing through the action of rotating screws, which disorganizes its original structure. Product quality can vary considerably depending on the extrusion processing variables (Camire, 2000). According to Huber (2000) processing variables may be divided into two categories: independent variables and dependent variables. Independent variables are those process parameters that the extruder operator can directly control. These variables include feed addition rate, water injection into the preconditioner, steam injection into the extruder, etc. Dependent variables are process parameters that change as a result of changing one or more of the independent variables. Dependent variables include retention time, temperature, and moisture in the preconditioner, moisture in the extruder, and mechanical energy input to the extruder. All final product characteristics are directly influenced by only four critical processing parameters. These four critical parameters are as follows: moisture, mechanical energy input, thermal energy input, and retention time (Huber, 2000).
In swine trials, extruder processing improved ileal and total tract digestibility of dry matter, gross energy, nitrogen and amino acids (Kim et al.,1994).

In recent years, expanders have been introduced into animal production. An expander is a device somewhat similar to an extruder yet requires less energy and maintenance input. Briefly, the feed passes into a conditioning chamber and through a thin gap between a cone shaped expander device and the chamber exit. The width of the gap and thus the mechanical pressure that is exerted on the feed is maintained by an adjustable hydraulic system. As feed passes the gap, a rise in temperature due to friction force occurs. Thus the feed not only undergoes a short-term temperature increase, but the feed particles also experience a shear force. Exposure to high temperature occurs for a short time so that destruction of heat sensitive nutrients appears to be minimal under normal conditions (Armstrong, 1993). Processing of feed with an expander prior to pelleting is widely used in Europe. According to Pipa and Frank (1989) expanders have several advantages: (1) more starch is gelatinized and this factor maximizes pellet durability and nutrient digestibility, (2) expanded feed can be pelleted easily and therefore pellet output is higher.

5. Utilization of exogenous enzymes and feed additives to reduce and eliminate anti-nutritional factors

The use of supplemental or exogenous enzymes has great potential to help improve nutrient availability from feedstuffs. Certain dietary enzymes have the ability to free up the carbohydrate and fiber portions of many cereals and by product ingredients for poultry. According to Ferket (1999), supplemental enzymes are usually substrate specific and provide the following benefits: (1) enzymes can increase the availability of storage polysaccharides and protein which would otherwise be inaccessible to endogenous enzymes, (2) enzymes can break down specific bonds in feedstuffs not usually degraded by endogenous enzymes, thus releasing more nutrients, (3) exogenous feed enzymes can help overcome inadequate digestion of young animals, where endogenous enzyme production may be limiting, and (4) they can break down various anti-nutritional factors in many feedstuffs, thus increasing the nutritional value. Zanella et al. (1999) demonstrated in broilers that enzyme supplementation of corn-soybean meal based diets with a cocktail of xylanase, protease, and amylase significantly improved CP digestibility by almost 3%, as well as starch, fat, and energy. Amino acid digestibility was similarly improved for 15 of 16 amino acids measured and significantly so for theronine, serine, glycine, valine, and tryptophan. In a performance trial with male broilers to 45 days of age, enzyme supplementation significantly improved body weight gain by 50 grams and feed conversion ratio by 4 points.

While there has been widespread use of exogenous enzymes to hydrolize non-starch polysaccharides (NSPs) in cereal grain, less attention has been paid to the protein component of ingredients. The cereal grains that constitute the bulk of animal feedstuffs also provide 30-60% of dietary amino acids (NRC, 1994). However, this protein is not necessarily fully digested by birds. The availability of amino acids is often limited by the presence of anti-nutritional factors (ANFs).

Processing technology is conventionally applied to soybeans, the most common being some form of heat treatment, which has proved most effective at reducing levels of trypsin inhibitors and soybean lectin. However, insufficiencies of some processing techniques have led to the development of biotechnological approaches such as the application of exogenous enzymes. Hessing et al. (1996) examined the ability of two microbial proteases (P1 and P2) to degrade ANFs, and to determine whether enzymatically hydrolyzed SBM could improve the productive performance of newly weaned piglets or broiler chicks. The SBM was pretreated with protease before feeding. SDS-PAGE and Western blotting analysis demonstrated that P1 could significantly hydrolyze the storage proteins glycinin and β-conglycinin at inclusion levels of 1,000-

10,000 U/gram material. It was concluded that the potential exists for protease enzymes to improve the nutritional value of soybean meal.

Phytate can bind with proteins at low and neutral pH (De Rham and Jost, 1979). Phytate-protein complexes may occur in foodstuffs in their native state or be formed in the upper gastrointestinal (GI) tract after eating. Phytate can also form complexes with proteolytic enzymes in the upper gastrointestinal tract potentially reducing the utilization of proteins and amino acids present in the GI tract. Yi et al. (1996) reported that apparent N retention of broiler chickens was improved when phytase was added to a 23% protein corn-soybean meal diet. Other work with both broilers and turkeys demonstrated significant improvements in the digestibility of amino acids and protein, when phytase was added to the diet (Ravindran et al., 1999). Furthermore, they reported mean digestibility of 15 essential amino acids in feedstuffs with and without added phytase (1,200 FTU/kg) in 5-week-old broilers was improved an average of 3.8%. However, the degree of impact may vary, depending on the specific composition of the diet.

6. Using multi-phase feeding to improve precision nutrition

Animals require fewer nutrients as they grow older due to changes in the maintenance requirement and the composition of growth. In addition, animals consume more feed as they grow heavier. The consequence of these factors is that young birds tend to have a relatively high requirement for protein and essential amino acids versus an older bird. Traditionally, broilers are fed 2-3 diets of decreasing protein content from day-old to slaughter. The NRC (1994) defined nutrient requirements for three fixed periods: starter, 0 to 3 weeks; grower, 3 to 6 weeks; and finisher, 6 to 8 weeks of age. Because the bird's needs change gradually with age, each diet can only be optimally balanced for a particular day. Assuming that the nutrient requirements set by the NRC are accurate, this day would be at approximately the midpoint of the age range over which the diet was fed; or for the starter, grower and finisher respectively at day 11, day 32 and day 49. At the beginning of the starter period the feed may be too low in protein and will be inadequate to support optimal growth. Moreover, at the end of the finisher period, the feed may be too high in protein, leading to excessive nitrogen excretion. Figure 2-2 illustrates the feeding of four diets for various time intervals and superimposes an "ideal protein" curve where the protein content is a function of age and changes gradually over the life span of the broiler. It illustrates that there are only 4 days in which the birds are receiving the optimum concentration of dietary protein throughout the production period. Phase fed diets are designed to meet the birds nutritional needs at specific points in the life cycle as illustrated earlier (Figure 2-2). Changing the diet several times in the course of the broiler's life is an attempt to better match nutritional requirements to the specific nutritional need and will usually improve feed efficiency.

Multi-phase feeding has been used in swine to decrease nitrogen excretion without sacrificing growth performance. Nitrogen excretion was reduced significantly during the early growing period (Kim et al., 2000). Boisen et al. (1991) studied the effect of multi-phase feeding on nitrogen excretion by increasing the number of feed phases for growing pigs from two to four.

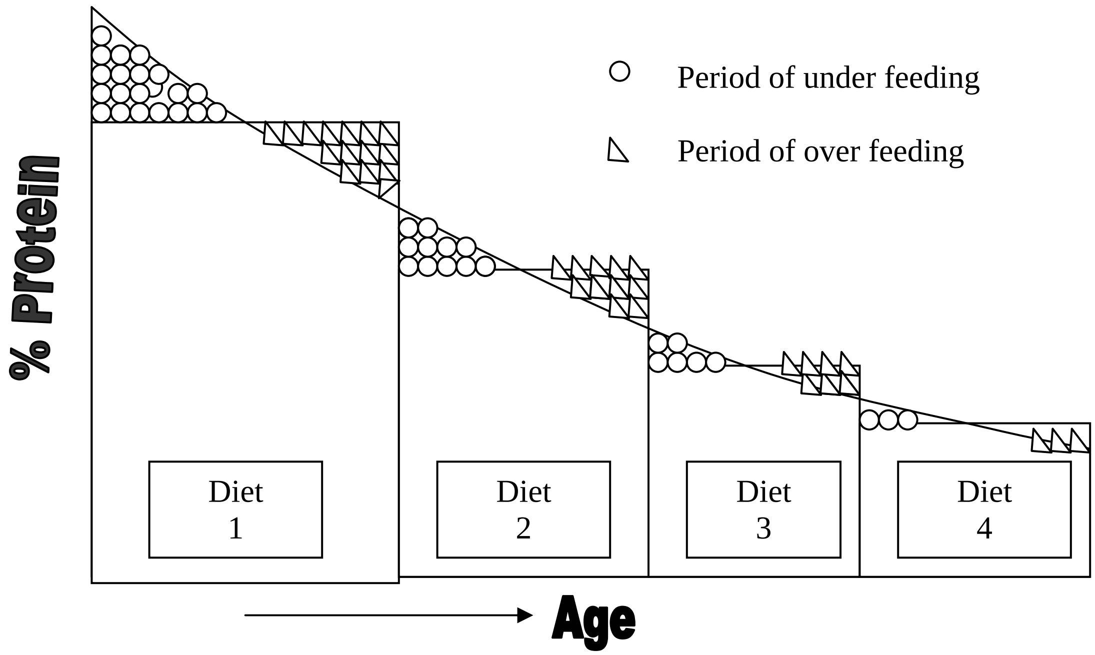

FIGURE 2-2. Effect of multi-phase feeding on protein requirement.

In this experiment, 20-95 kg pigs were fed 2-phase high protein diets containing 27 and 23% protein versus 4-phase diets containing 30, 25, 21 and 16% protein. Two phase low protein diets (14 and 10%) were also compared with four-phase diets containing 18, 13, 9 and 5% protein. The resulting nitrogen excretion was reduced by 5% on both high and low protein four-phase diets. Koch (1990) estimated (based on theoretical calculations) that nitrogen and phosphorus excretion could be reduced by 13% by utilizing two grower-finisher diets versus a single diet.

Another advantage of multi-phase feeding is reduced diet cost. Bell (1998) compared two phase feeding to multi-phase feeding (3, 4, 5, 6, 9 and 12 phases) and found diet cost per pig significantly decreased as the number of feed phases increased. Increasing the number of phases in poultry feeding programs yields benefits similar to those observed in swine, although it creates more problems with respect to delivery systems.

Warren and Emmert (2000) studied multi-phase feeding during the starter period using three distinct diets (0 to 7, 7 to 14 and 14 to 21 days) and reported no significant differences in weight gain, feed intake, and feed efficiency. Pope et al. (2002) studied multi-phase feeding in broilers from 32 to 63 days of age, and found no difference in weight gain, feed intake, feed efficiency and carcass composition. Cost of production was reduced, however.

To adjust dietary protein content as birds get older, some European farmers/companies have literally added 100 or 150 g/kg whole grain on top of each load of broiler grower or finisher feed as it leaves the mill. In Denmark, whole-wheat addition to broiler diets has been practiced since 1984 (Belyavin, 1999). Wheat is typically introduced into the diet from day 12 at 50 g/kg inclusion, rising to 300 g/kg at 35 days until the birds go for processing. This practical application is based on the belief that the individual chickens can make nutritional corrections by selecting pelleted feed or whole wheat as needed based on their specific daily requirement. Guray et al. (2003) studied the effects of three different choice feeding methods based on whole wheat on broiler performance. In their experiment they used four treatments: control, compound feed and wheat mixture, compound feed and whole wheat in separate troughs, and standard compound feed (18 hours) and whole wheat (6 hours) sequentially. The results indicated compound feed and whole wheat in separate troughs method was more effective compared to the others. In one study reported by Cowan and Michie (1978), male and female broilers were fed either a complete diet or given a choice of whole wheat and one of two higher protein feeds formulated by omitting some or all of the cereal from the complete diet. Interestingly, they found that the female birds were not as capable as the males in controlling their daily protein intake. Unfortunately, top dressing with whole wheat will never provide the optimum nutrient profile and could lead to amino acid imbalances and other nutritional problems.

An even better strategy to match feed composition to the broiler's specific nutritional requirements during progressive periods of growth may be "continuous multi-phase feeding." Continuous multi-phase feeding can be accomplished by providing a nutritionally complete high and low protein feed in two separate bins and blending finished feeds at the point of load-out. Augers convey each feed to a common weigher/mixer, which under computer control, can make the optimal mixed diet according to the age and needs of the birds. A sophisticated approach to the concept described above has been developed beyond the theoretical stage and is in current use on commercial farms. One such example, Flockman™, a company based in England offers a technology to blend a cereal grain with a concentrate at the live production facility using a computer control system. The equipment weighs the feed delivered to the birds each day, records daily feed consumption and blends a cereal grain with concentrate to meet the birds precise requirements each day (Figure 2-3).

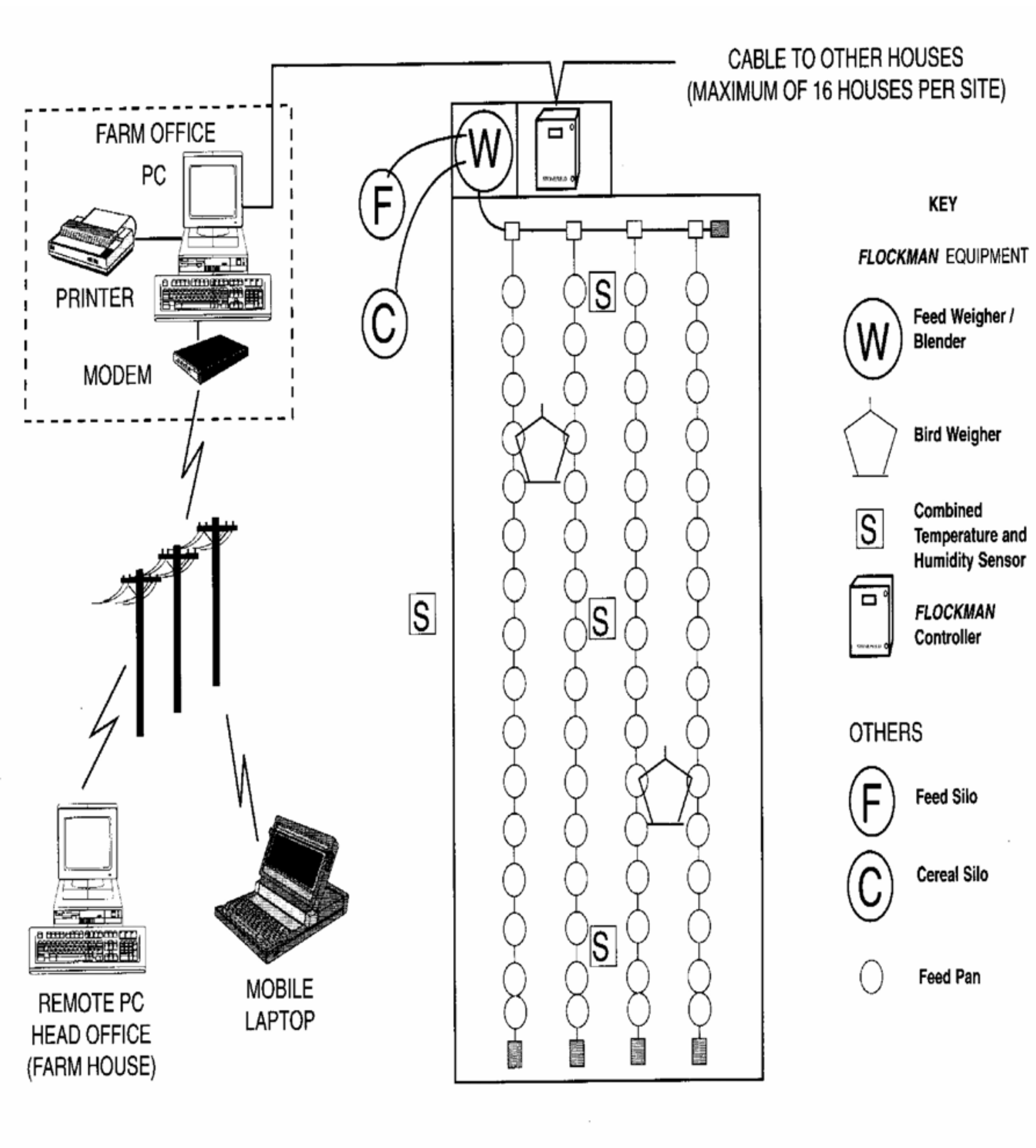

FIGURE 2-3. Diagram of a Flockman^{TM} house layout for broilers. (**www.flockman.com**).

A phase-feeding approach could also be used to significantly reduce phosphorus (P) excretion, since P requirements are closely associated with skeletal development. Because skeletal development decreases substantially as animals grow older, the potential for reducing P excretion increases correspondently. Ling et al. (2000) evaluated a four-phase feeding program to more accurately determine the non-phytate P needs of broilers. The four-phases studied were: starter, hatch to 18 days of age; grower, 18 to 32 days of age; finisher, 32 to 42 days of age; and withdrawal, 42 to 49 days of age. They found that in comparison to average commercial usage levels, non-phytate P could be reduced by 5% in the grower diet and 15% in the finisher diet without affecting bone strength and performance.

The research that follows evaluates multi-phase feeding systems to reduce nitrogen excretion in broiler manure and optimize broiler performance. For the first and second experiments, continuous multi-phase feeding (changing diets every day) are compared to single-phase feeding. Then for the third and fourth experiments, a four-phase industry type feeding program is compared to intensive multi-phase feeding (changing diets every three days) during a 7 week grow out period.

CHAPTER III

EFFECT OF CONTINUOUS MULTI-PHASE FEEDING ON PERFORMANCE AND FECAL NITROGEN CONTENT OF STARTER BROILER CHICKENS

INTRODUCTION

The importance of describing and understanding the growth of broiler chicks during their early life has increased because of increasingly shorter production periods as genetic improvements are made. Early nutrition seems to be critical for optimum performance. Lilja (1983) has proposed that the ultimate growth of the bird is directly proportional to early development of those systems that supply substrate to the rest of the body, specifically the gastrointestinal and cardiovascular systems.

When a bird is young it has a small maintenance requirement but its growth potential is enormous. The older bird tends to have high maintenance and little or no growth requirements. As a consequence, the young bird has a relatively high requirement for protein and essential amino acids and the requirement of the older animal is comparatively low (Belyavin, 1999). The NRC (1994) set single protein and amino acid requirements of broiler chickens for a three week starter period. This approach theoretically leads to periods of under feeding initially and over feeding toward the end of the 3-week starter period. When protein is underfed, the maximum genetic potential for growth may not be achieved and efficiency of feed utilization will be poor. When protein is overfed, the excess nitrogen is deaminated and excreted which can result in a negative impact to the environment and a major concern for livestock producers around the world (Kornegay, 1996).

A strategy to match feed composition to the broiler's nutritional requirements during progressive periods of growth is called "phase feeding." Phase fed diets are designed to meet the bird's nutritional needs at a given point in the life cycle. Changing the diet several times in the course of the broiler's life in order to better match nutritional requirements to the specific nutritional need will usually improve feed efficiency.

Multi-phase feeding has been used in swine to decrease nitrogen excretion without sacrificing growth performance (Boisen et al., 1991; Kim et al., 2000). The other advantage of multi-phase feeding is reduced diet cost (Bell, 1998), although it creates more problems with respect to delivery systems. Recently, Flockman™ a company based in England, has offered a technology to blend a cereal grain with a concentrate at the live animal production facility using a computer control system. This system has been used successfully in Europe but is not prevalent in the United States.

Multi-phase feeding does not always result in improved performance. Warren and Emmert (2000), studied phase feeding during the broiler starter period using three diets (0 to 7, 7 to 14 and 14 to 21 days) and reported no significant differences in weight gain, feed intake or feed efficiency.

The objective of this study was to compare broiler performance using continuous multi-phase feeding whereby diets are changed to meet the broilers requirement on a daily basis versus single-phase feeding during a 3-week starter period

MATERIALS AND METHODS

Two experiments were conducted utilizing straight run broiler chicks of a Ross x Cob strain. In experiment 1, 144 day-old broilers were randomly placed in 24 separate battery brooder pens (6 chicks per pen). Treatments consisted of a single-phase feeding program and a multi-phase feeding program in which the diets were changed on a daily basis. There were 12 replicate pens per treatment. The treatments were created by blending 2 basal diets: Diet A, 24% protein, 3124 kcal ME/kg and diet B, 20% protein, 3168 kcal ME/kg (Table 3-1). For the single-phase treatment, both diets were mixed together at a 1:1 ratio and fed continually for 21-d. Nutrient composition of the single-phase diet averaged: 3146 kcal/kg poultry ME, 22% protein, 1.22% lysine, 0.51% methionine, 0.93% calcium and 0.43% available phosphorus. The multi-phase diets were created by linearly blending the 2 basal diets; Diet A was reduced from 100%, 95%, …., to 0% and diet B was increased from 0%, 5%, …., to 100% (Table 3-2).

All diets were fed in the mash form and provided *ad libitum.* Uneaten feed was collected and weighed every day. Uneaten multi-phase feeds were discarded after weighing. Remaining single-phase feed was supplemented with fresh feed and reused. Water was freely available throughout the study and the light remained on 24-h per day. The birds were weighed by pen every day. A metal tray was placed under each pen, and excreta was collected and weighed daily at approximately 4:00 PM. All samples were kept in the freezer until they could be analyzed for nitrogen and dry matter. No attempt was made to immediately acidify the feces thus one can presume some nitrogen was lost as ammonia prior to analysis.

TABLE 3-1. Composition and analyses of experimental diets

Ingredient	Experiment 1		Experiment 2	
	Diet A	Diet B	Diet A	Diet B
Corn	50.81	62.25	45.21	63.22
Dehulled Soybean Meal	40.31	30.00	45.13	29.25
DL-Methionine	0.20	0.16	0.20	0.15
L-Lysine HCl	0.02	0.07	-	0.09
Fat, A&V Blend	4.78	3.80	5.56	3.64
Limestone	1.54	1.55	1.65	1.55
Mono-dicalcium PO4	1.53	1.35	1.50	1.36
Salt	0.39	0.39	0.39	0.39
Trace Minerals[1]	0.05	0.05	0.05	0.05
Vitamins[2]	0.30	0.30	0.30	0.30
Coban 60	0.08	0.08	-	-
Calculated Nutrient Content				
Crude Protein (%)	24.00	20.00	26.00	20.00
Energy (kcal ME/kg)	3124	3168	3200	3200
Methionine (%)	0.55	0.46	0.58	0.46
Lysine (%)	1.34	1.10	1.45	1.10
Calcium (%)	0.95	0.90	1.00	0.90
Non-phytate Phosphorus (%)	0.45	0.40	0.45	0.40

[1]Trace mineral premix provided 149.6 mg manganese, 125.4 mg zinc, 16.5 mg iron, 1.7 mg copper, 1.05 mg iodine, 0.25 mg selenium, a minimum of 6.27 mg calcium and a maximum of 8.69 mg calcium per kg of diet.

[2]Vitamin premix provided 11,023 IU vitamin A, 3,858 IU vitamin D, 46 IU vitamin E, 0.0165 mg B_{12}, 5.845 mg riboflavin, 45.93 mg niacin, 477.67 mg choline, 20.21 mg d-pantothenic acid, 1.47 mg menadione, 1.75 mg folic acid, 2.94 mg thiamine, 7.17 mg pyridoxine, 0.55 mg biotin per kg diet.

TABLE 3-2. Calculated nutrient composition of multi-phase diets (experiment 1)

Days	Calculated nutrient content					
	ME Kcal/kg	Protein (%)	Lysine (%)	Methionine (%)	Ca (%)	Av. P (%)
1	3124	24.00[1]	1.34	0.58	0.95	0.45
2	3126	23.80	1.33	0.57	0.95	0.45
3	3128	23.60	1.32	0.57	0.95	0.45
4	3131	23.40	1.30	0.56	0.94	0.44
5	3133	23.20	1.29	0.56	0.94	0.44
6	3135	23.00	1.28	0.55	0.94	0.44
7	3137	22.80	1.27	0.54	0.94	0.44
8	3139	22.60	1.26	0.54	0.93	0.43
9	3142	22.40	1.24	0.53	0.93	0.43
10	3144	22.20	1.23	0.53	0.93	0.43
11	3146	22.00	1.22	0.52	0.93	0.43
12	3148	21.80	1.21	0.51	0.92	0.42
13	3150	21.60	1.20	0.51	0.92	0.42
14	3153	21.40	1.18	0.50	0.92	0.42
15	3155	21.20	1.17	0.50	0.92	0.42
16	3157	21.00	1.16	0.49	0.91	0.41
17	3159	20.80	1.15	0.48	0.91	0.41
18	3161	20.60	1.14	0.48	0.91	0.41
19	3164	20.40	1.12	0.47	0.91	0.41
20	3166	20.20	1.11	0.47	0.90	0.40
21	3168	20.00[2]	1.10	0.46	0.90	0.40

[1] Actual protein analysis: 23.8%.
[2] Actual protein analysis: 20.1%.

The combustion method (LECO™[3] analyzer) was used for DM nitrogen analyses of samples collected on day 7, 14 and 21 of the experiment.

Experiment 2 was similar to experiment 1, with a few exceptions. A total of 24 day-old broilers were individually caged and diets were based on NRC (1994) requirements for protein and energy. The single-phase diet contained: 3200 kcal/kg poultry ME, 23% protein, 1.28% lysine, 0.52% methionine, 0.95% calcium and 0.43% available phosphorus. The blended diets ranged from 26 to 20% protein with metabolizable energy maintained at 3200 kcal ME/kg (Table 3-3). This blending strategy implied the NRC (1994) requirement at 23% protein was optimized for the specific period midway between the 21 day starter period. The single-phase diet was completely replaced with fresh feed every day.

Statistical Analysis

Both experiments were analyzed by T-Test using the mixed procedure of SAS® (SAS Institute, 1996). Regression analyses were used to test the association between data over time. Statements of significance were based on $P \leq 0.05$.

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[3]LECO FP-2000 Nitrogen Analyzer, St. Joseph, MI 49085.

TABLE 3-3. Calculated nutrient composition of multi-phase diets (experiment 2)

Days	Calculated nutrient content					
	ME Kcal/kg	Protein (%)	Lysine (%)	Methionine (%)	Ca (%)	Av. P (%)
1	3200	26.00	1.45	0.58	1.00	0.45
2	3200	25.70	1.43	0.57	1.00	0.45
3	3200	25.40	1.42	0.57	0.99	0.45
4	3200	25.10	1.40	0.56	0.99	0.44
5	3200	24.80	1.38	0.56	0.98	0.44
6	3200	24.50	1.36	0.55	0.98	0.44
7	3200	24.20	1.35	0.54	0.97	0.44
8	3200	23.90	1.33	0.54	0.97	0.43
9	3200	23.60	1.31	0.53	0.96	0.43
10	3200	23.30	1.29	0.53	0.96	0.43
11	3200	23.00	1.28	0.52	0.95	0.43
12	3200	22.70	1.26	0.51	0.95	0.42
13	3200	22.40	1.24	0.51	0.94	0.42
14	3200	22.10	1.22	0.50	0.94	0.42
15	3200	21.80	1.21	0.50	0.93	0.42
16	3200	21.50	1.19	0.49	0.93	0.41
17	3200	21.20	1.17	0.48	0.92	0.41
18	3200	20.90	1.15	0.48	0.92	0.41
19	3200	20.60	1.14	0.47	0.91	0.41
20	3200	20.30	1.12	0.47	0.91	0.40
21	3200	20.00[2]	1.10	0.46	0.90	0.40

[1] Actual protein analysis: 25.6%.
[2] Actual protein analysis: 19.7%.

RESULTS AND DISCUSSION

In experiment 1, there were no significant differences in weight gain, feed consumption, feed to gain ratio or fecal nitrogen content (Table 3-4 and Figures 3-1, 3-2, 3-3, 3-4). This was somewhat unexpected as it was thought, the continuous multi-phase feeding program would result in improved performance early in the starter period when the more concentrated diets were being fed. Through changing the diets daily we had hoped the nutritional composition of the diets (especially protein) would more closely match the birds' specific daily requirements. There was a tendency for birds raised on the multi-phase feeding program to have higher feed consumption but slightly lower weight gain as compared to the birds raised on the single-phase feeding program. This was totally unexpected, but could be due to our feeding technique, in which we changed the feed for the multi-phase feeding program every day in contrast to top-dressing the previous days feed for the single-phase birds. An analysis of the single-phase feed remaining at the end of the study revealed a significantly higher protein content than was originally present suggesting the birds were selectively picking out pieces of ground corn. To address this problem, experiment 2 was conducted using a slightly different technique in which both the single-phase and multi-phase diets, were both changed out every day.

In Experiment 2, we again saw no significant differences in feed consumption, daily gain, feed to gain ratio or nitrogen excretion (Tables 3-5, 3-6 and Figures 3-5, 3-6, 3-7).

TABLE 3-4. Effect of multi-phase feeding on daily gain, feed consumption and feed to gain ratio for broilers (experiment 1)

Day	Daily gain (g/bird/day)		Daily feed consumption (g/bird/day)		Feed to gain ratio	
	Multi-Phase	Single-phase	Multi-Phase	Single-phase	Multi-phase	Single-phase
1	8.7±0.6	8.6±1.0	7.26±0.6	8.32±0.9	0.84±0.09	0.97±0.06
2	7.8±1.0	7.6±0.7	9.48±0.9	8.90±1.3	1.22±0.07	1.17±0.11
3	13.8±0.6	13.3±0.6	14.44±0.6	13.74±1.1	1.05±0.05	1.03±0.03
4	15.3±0.7	15.0±0.8	19.27±0.8	17.96±1.1	1.26±0.09	1.32±0.08
5	17.5±0.8	17.2±0.6	24.39±2.9	21.57±1.2	1.39±0.09	1.25±0.07
6	20.1±0.9	19.2±0.8	27.63±2.2	25.35±1.4	1.37±0.06	1.32±0.05
7	21.7±1.0	20.4±0.8	31.71±1.7	28.43±1.4	1.46±0.08	1.39±0.02
8	23.9±0. 9	21.8±1.8	35.41±2.0	32.16±1.8	1.48±0.08	1.47±0.03
9	28.6±1.3	26.0±1.8	39.74±2.4	35.94±2.3	1.39±0.07	1.38±0.05
10	26.3±1.7	26.6±1.1	43.89±1.3	40.10±1.9	1.67±0.09	1.51±0.13
11	35.2±1.4	35.5±1.6	48.47±1.0	44.98±1.9	1.38±0.07	1.27±0.06
12	32.7±1.4	34.5±1.8	53.29±1.2	50.19±1.9	1.63±0.11	1.46±0.12
13	36.9±3.3	40.1±3.6	57.93±1.7	55.06±1.9	1.57±0.11	1.37±0.13
14	41.1±2.0	43.0±2.1	63.48±2.7	62.26±2.9	1.54±0.09	1.45±0.11
15	42.4±2.4	43.8±2.2	69.46±1.9	64.35±2.9	1.64±0.12	1.47±0.12
16	45.0±1.4	46.8±1.4	71.73±2.0	66.71±2.7	1.59±0.12	1.42±0.11
17	43.6±2.5	44.5±1.7	78.27±3.8	71.95±3.4	1.79±0.01	1.62±0.02
18	47.4±2.8	53.6±3.5	78.51±3.9	76.90±3.4	1.65±0.01	1.44±0.02
19	52.2±2.0	49.5±2.4	82.85±3.3	79.89±2.0	1.59±0.08	1.62±0.06
20	51.7±4.5	51.8±2.9	77.68±2.9	83.08±2.5	1.51±0.08	1.60±0.04
21	54.2±3.1	54.5±4.1	81.75±2.8	86.44±3.01	1.51±0.06	1.59±0.08
			Cumulative data per week			
W 1	104.9±4	101.3±4	134.1±8	124.27±10	1.28±0.04	1.23±0.06
W 2	329.6±7	328.8±10	476.39±28	444.96±26	1.44±0.12	1.35±0.09
W 3	666.1±14	673.3±13.7	1016.6±22	974.3±30.1	1.52±0.13	1.45±0.11

Average hatch weight = 40 gram, Values are mean ± SEM.

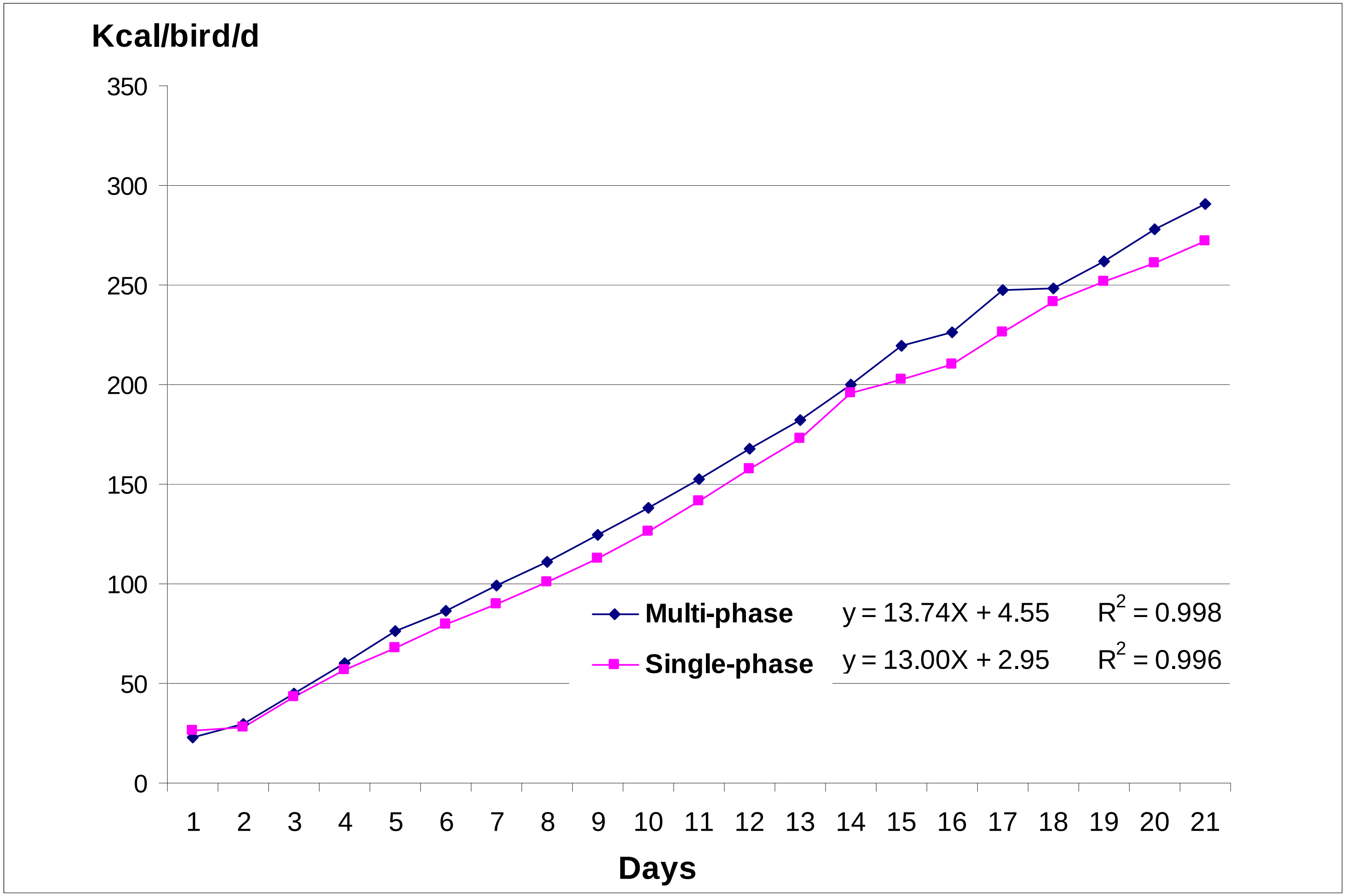

FIGURE 3-1. Calculated daily metabolizable energy consumption (experiment 1).

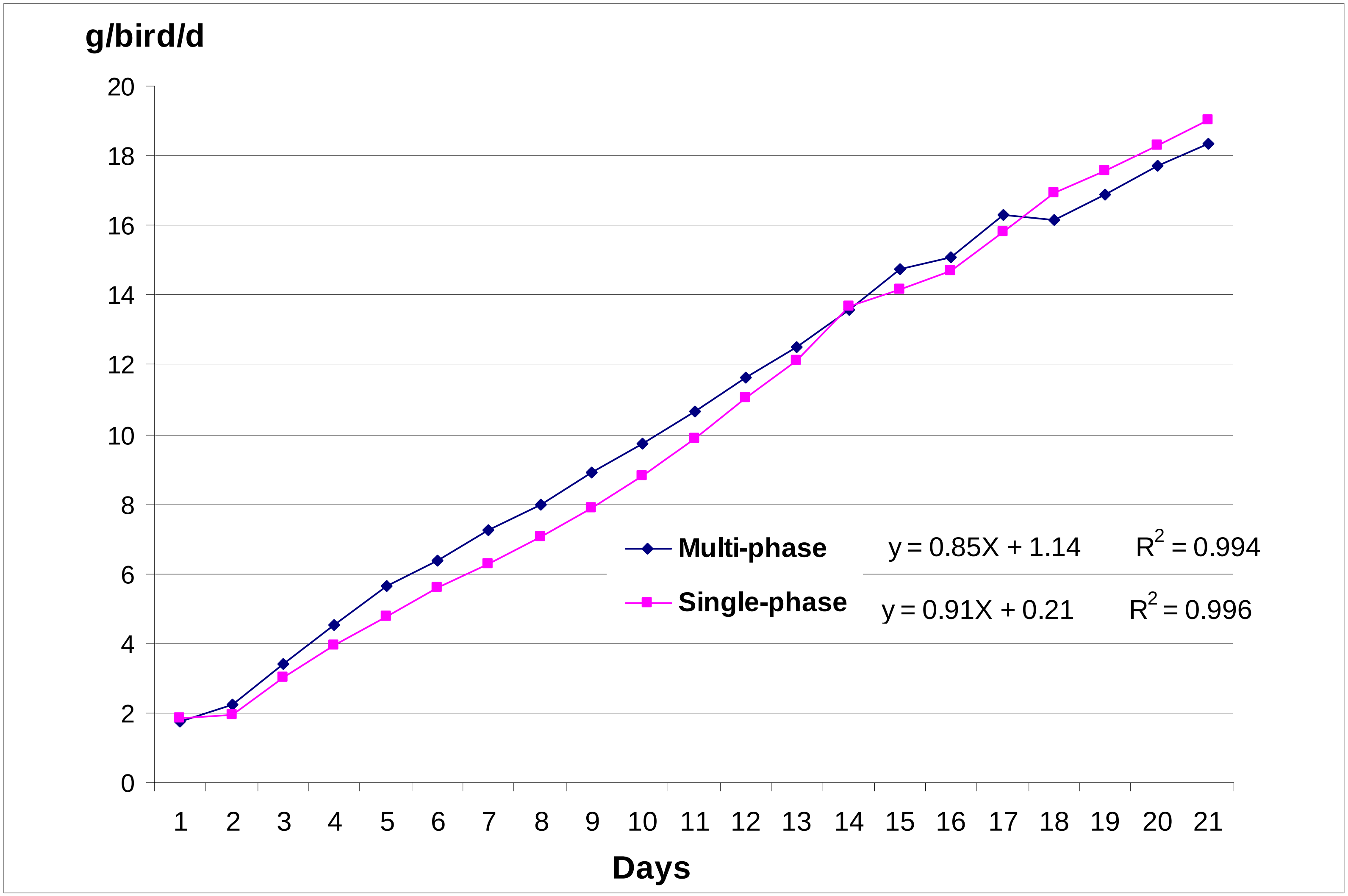

FIGURE 3-2. Calculated daily protein consumption (experiment 1).

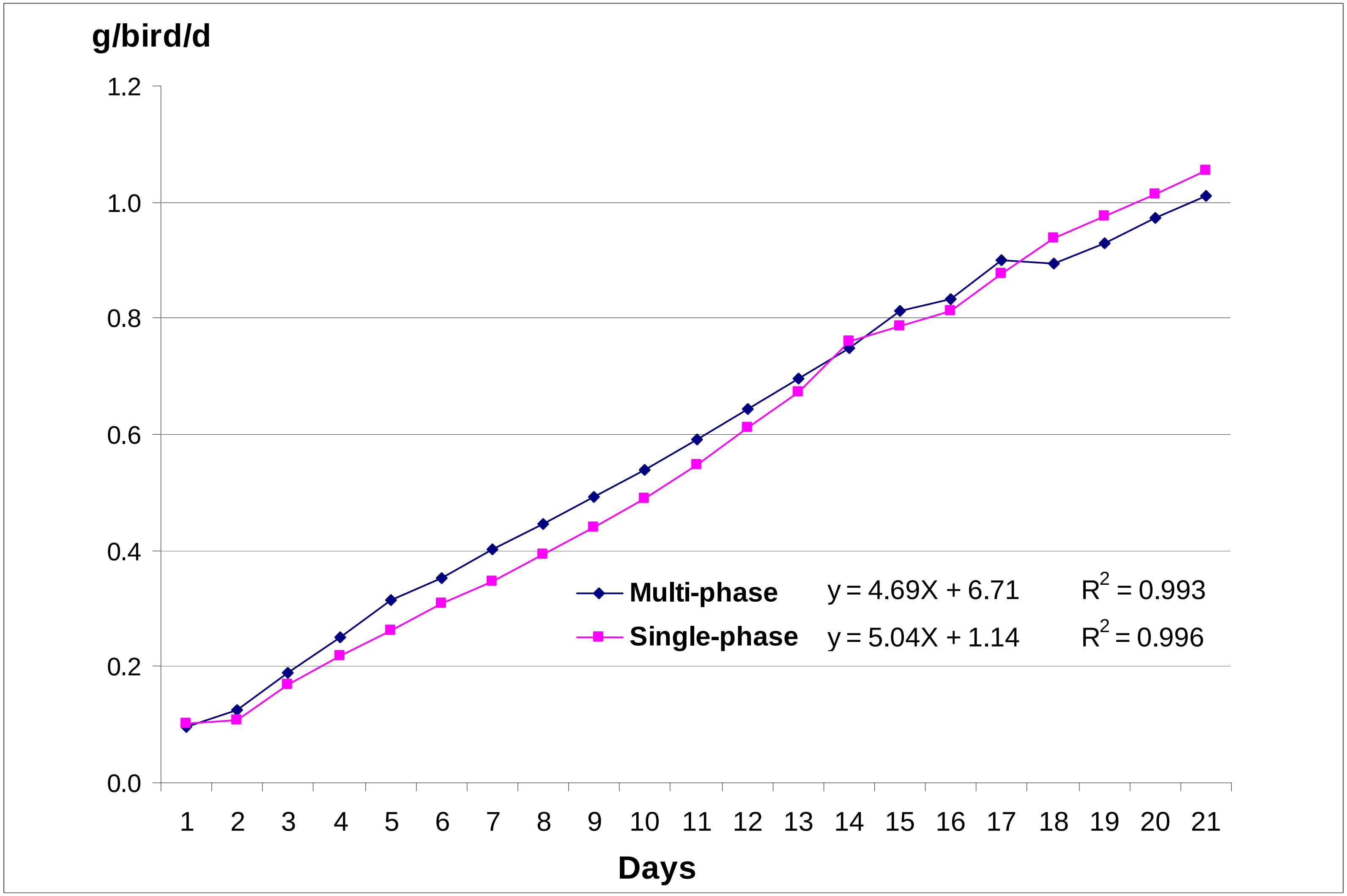

FIGURE 3-3. Calculated daily lysine consumption (experiment 1).

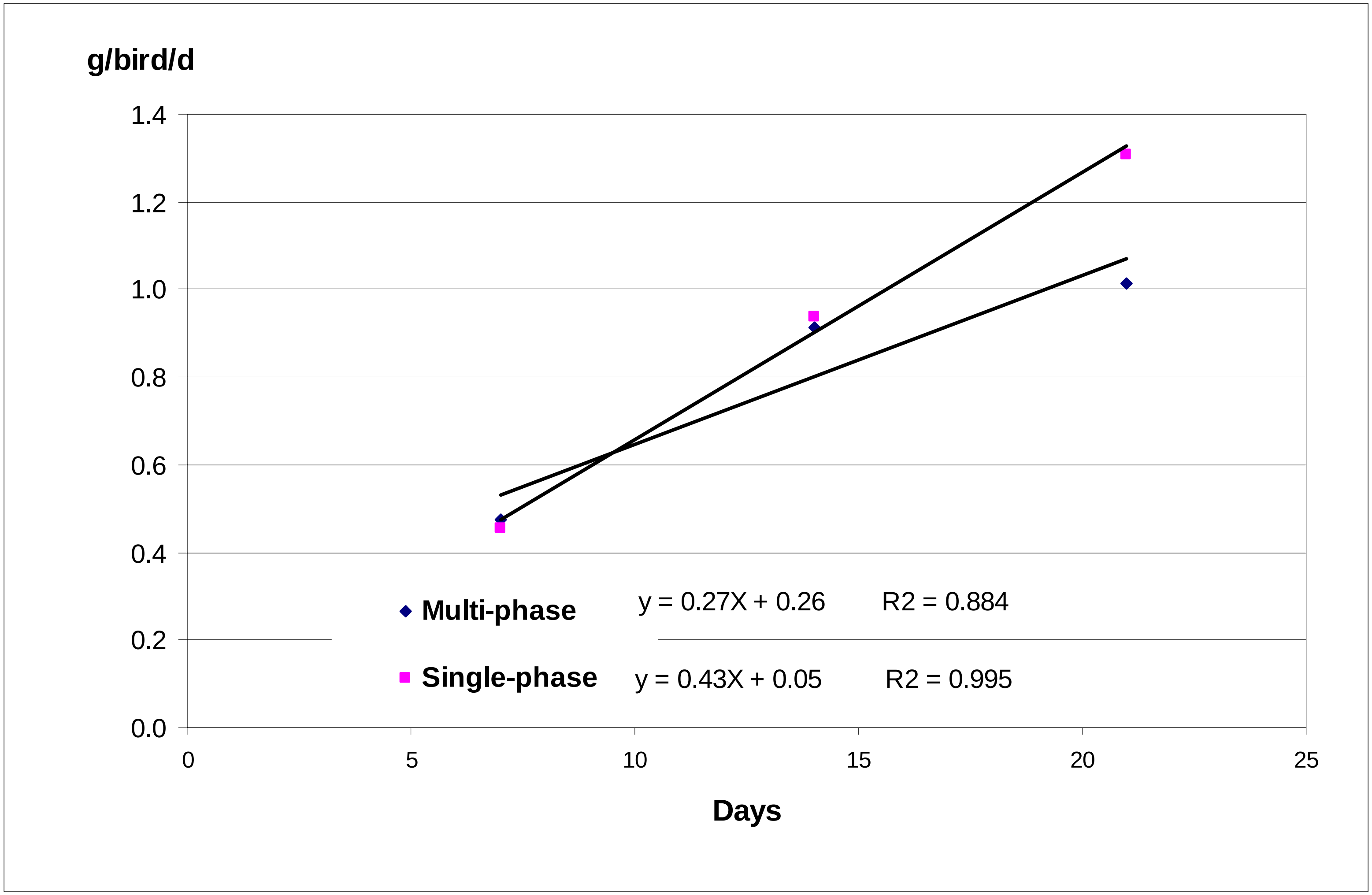

FIGURE 3-4. Average fecal nitrogen content for days 7, 14 and 21 (experiment 1).

TABLE 3-5. Effect of multi-phase feeding on daily gain, feed consumption and feed to gain ratio for broilers (experiment 2)

Day	Daily gain (g/bird/day)		Daily feed consumption (g/bird/day)		Feed to gain ratio	
	Multi-phase	Single-phase	Multi-phase	Single-phase	Multi-phase	Single-phase
1	2.34±1.5	2.13±1.8	2.42±0.9	2.83±1.3	1.03±0.12	1.33±0.02
2	6.45±1.9	6.91±2.3	6.63±0.8	6.94±1.2	1.03±0.03	1.00±0.02
3	10.27±0.9	10.91±0.7	10.91±0.6	11.73±1.1	1.06±0.03	1.08±0.02
4	11.95±1.2	11.42±1.1	11.27±0.7	13.25±1.4.	0.94±0.02	1.16±0.02
5	12.15±1.6	15.67±1.4	17.29±0.8	19.43±1.2	1.42±0.02	1.24±0.01
6	14.76±1.3	15.73±1.4	19.25±1.2	21.95±1.4	1.30±0.01	1.40±0.02
7	16.39±1.4	17.96±2.1	23.12±1.6	24.87±1.4	1.41±0.02	1.38±0.03
8	21.13±2.3	20.69±2.2	27.12±2.0	28.42±1.8	1.28±0.02	1.37±0.02
9	24.64±3.3	24.75±3.2	28.60±2.3	28.03±2.2	1.16±0.03	1.13±0.03
10	27.39±3.7	27.14±2.1	30.80±1.3	32.19±1.9	1.13±0.03	1.19±0.07
11	29.67±3.0	30.66±2.2	38.88±0.1	39.53±1.5	1.31±0.03	1.29±0.04
12	36.12±3.8	31.71±2.3	43.63±1.1	43.42±1.0	1.21±0.04	1.37±0.04
13	35.55±1.8	35.55±2.1	46.18±1.7	45.27±1.6	1.30±0.03	1.27±0.08
14	29.35±3.1	32.89±2.8	44.09±1.7	47.27±1.9	1.50±0.03	1.44±0.07
15	36.37±3.0	37.93±3.0	51.00±1.9	48.44±1.9	1.40±0.06	1.28±0.05
16	37.13±1.9	34.88±2.4	51.41±2.0	47.76±1.7	1.38±0.06	1.37±0.09
17	42.57±3.3	37.88±3.7	52.12±2.8	50.12±3.0	1.22±0.08	1.32±0.07
18	43.34±2.3	44.45±3.8	59.65±2.9	55.88±3.1	1.38±0.09	1.26±0.10
19	47.69±3.20	44.60±3.3	69.62±4.3	60.05±2.0	1.46±0.07	1.35±0.08
20	45.41±4.2	41.95±5.8	71.32±3.9	67.32±4.5	1.57±0.08	1.60±0.07
21	51.63±5.9	44.06±6.05	90.23±4.9	82.98±5.5	1.75±0.09	1.88±0.15
			Cumulative data per week			
W 1	74.32±5.4	80.73±3.6	90.88±7.4	101.00±7.2	1.22±0.02	1.25±0.03
W 2	278.16±4.8	284.12±6.9	350.19±4.2	365.13±7.8	1.26±0.03	1.28±0.04
W 3	582.3±19	569.87±13	795.54±15	777.68±16	1.37±0.06	1.36±0.05

Average hatch weight = 40 gram. Values are mean ± SEM.

Ferguson et al. (1998) reported that a reduction in crude protein from 26 to 22% during the starter period (1-21 days) did not effect live weight gains but did reduce gain over the 22 to 43 days when protein declined from 21 to 16.5%. Other authors also observed equal weight gain and feed efficiency when comparing high protein versus low protein diets supplemented with amino acids from day 7 to day 21 (Parr and Summers, 1991; Han et al., 1992).

Although in this experiment we set the lysine content for the multi-phase feeding initially fairly high (1.45%) compared to the NRC requirement (1.1%), or Illinois Ideal Chick Protein requirement (1.02%) we did not observe a significant effect on performance. Baker and Han (1994) compared NRC 1984 and 1994 profiles, in which the lysine requirement was lowered from 1.2% to 1.1% and found chicks performed markedly better when fed with the NRC 1994 profile compared to the NRC 1984 profile. They also compared the NRC (1994) profile with the lower ratio IICP profile using diets containing only 0.9% lysine, and found there were no significant differences in weight gain, feed intake, or feed conversion ratio.

One explanation for the failure to observe significant differences in performance may be due to the relatively high lysine content (1.29%) of the control diet which was almost 0.2% higher than the NRC (1994) recomendation. Some studies have shown that broilers may be switched to a less nutrient-dense grower diet earlier than 3 weeks of age without sacrificing growth performance or carcass yield (Watkins et al., 1993; Saleh et al., 1995). Calculated metabolizable energy, protein and lysine consumption in both experiments (Figures 3-2, 3-3, 3-6 and 3-7) were fairly similar and did not vary as much as expected even though the nutrient content of the multi-phase diets changed every day.

TABLE 3-6. Effect of multi-phase feeding on nitrogen intake and fecal nitrogen content (experiment 2)

Day	N-intake (g/day/bird)		N-excreted (g/d/bird)	
	Multi-hase	Single-phase	Multi-phase	Single-phase
1	0.10±0.01	0.12±0.01	-	-
2	0.27±0.01	0.25±0.02	-	-
3	0.44±0.02	0.42±0.01	0.13±0.01	0.12±0.01
4	0.45±0.01	0.48±0.01	0.21±0.02	0.18±0.02
5	0.68±0.02	0.70±0.01	0.23±0.02	0.22±0.02
6	0.75±0.03	0.79±0.02	0.25±0.03	0.23±0.03
7	0.90±0.04	0.90±0.03	0.46±0.07	0.37±0.06
8	1.04±0.03	1.09±0.04	0.57±0.05	0.44±0.04
9	1.08±0.02	1.01±0.04	0.62±0.07	0.49±0.05
10	1.15±0.05	1.16±0.03	n/a	n/a
11	1.45±0.03	1.43±0.03	n/a	n/a
12	1.58±0.04	1.57±0.05	n/a	n/a
13	1.64±0.03	1.64±0.02	0.78±0.09	0.67±0.08
14	1.56±0.03	1.71±0.03	0.84±0.06	0.87±0.09
15	1.78±0.05	1.75±0.05	0.89±0.07	0.97±0.07
16	1.75±0.06	1.73±0.04	0.83±0.04	0.94±0.07
17	1.77±0.03	1.81±0.03	1.00±0.05	1.00±0.09
18	1.97±0.05	2.02±0.02	0.83±0.05	0.81±0.08
19	2.29±0.12	2.17±0.13	0.94±0.05	0.82±0.07
20	2.29±0.13	2.43±0.14	1.20±0.09	1.16±0.09
21	2.83±0.15	3.00±0.16	1.39±0.12	1.26±0.11

Values are mean ± SEM.
n/a: Data not available because the drying oven malfunctioned.

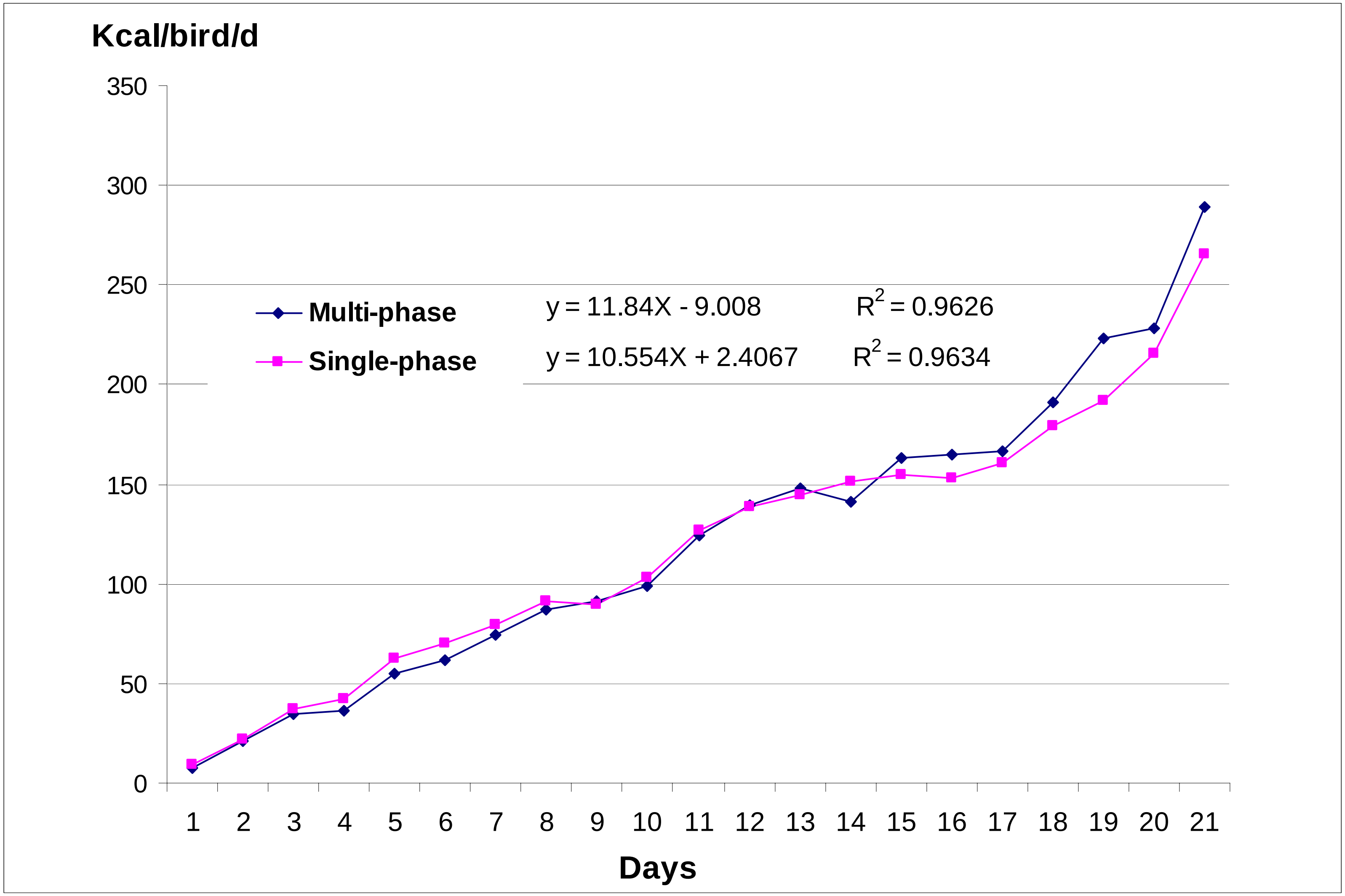

FIGURE 3-5. Calculated daily metabolizable energy consumption (experiment 2).

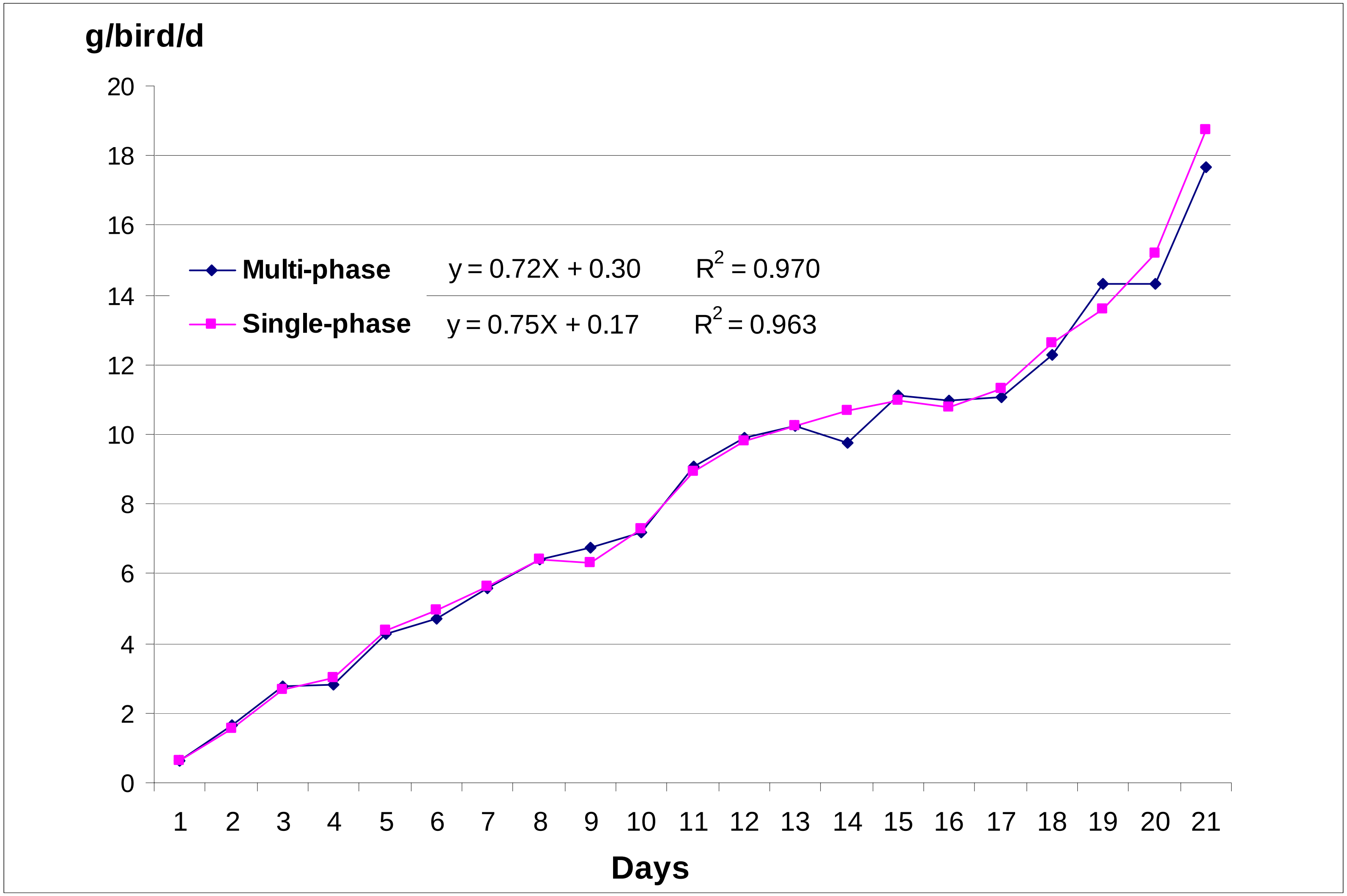

FIGURE 3-6. Daily protein consumption (experiment 2).

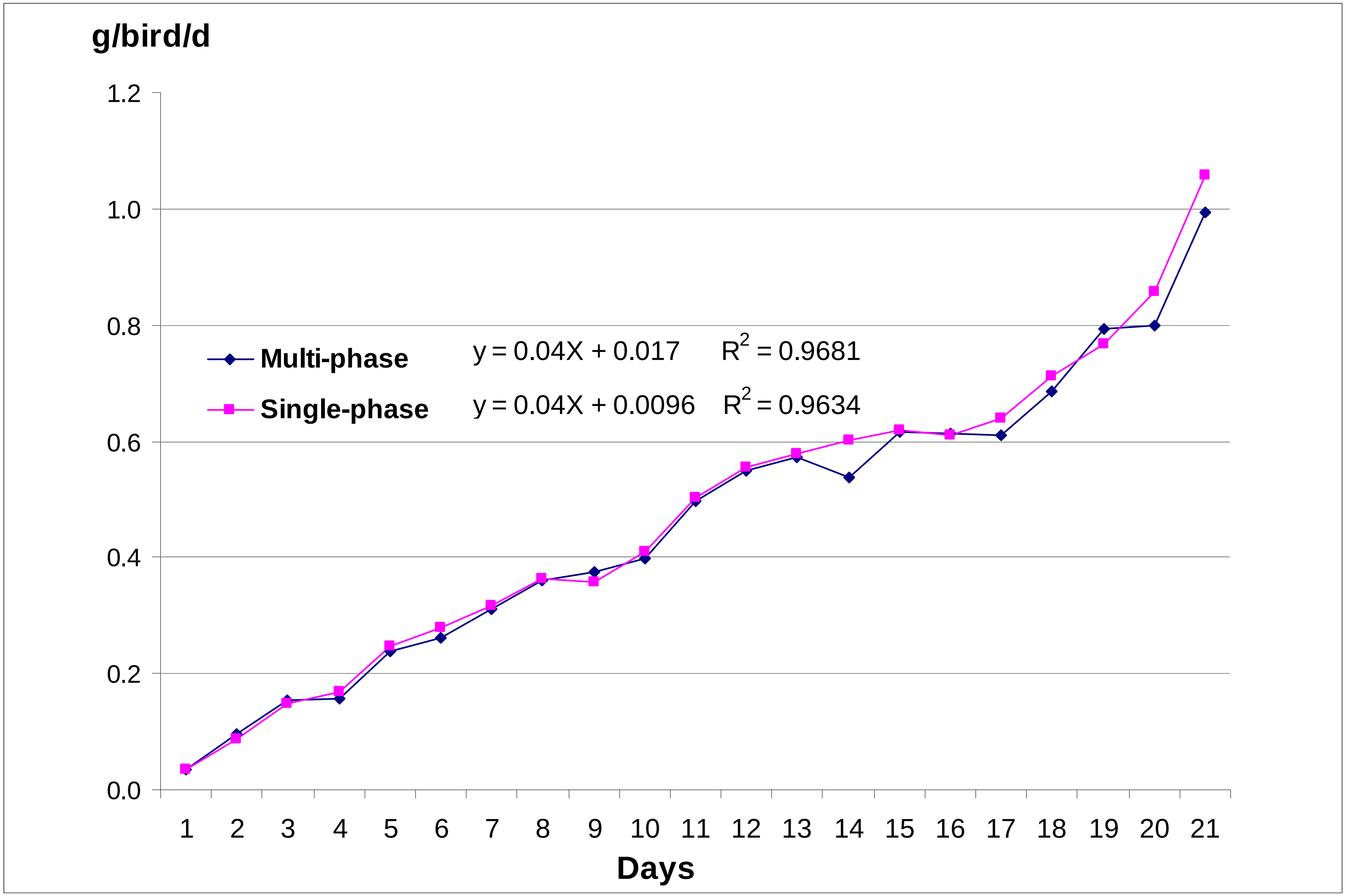

FIGURE 3-7. Calculated daily lysine consumption (experiment 2).

For experiment 2 it appears the birds on the multi-phase treatment were increasing consumption slightly to adjust for decreased dietary protein during the last few days of the study even though the dietary metabolizable energy was constant at 3200 kcal/kg. This varies a little from observations of Larbier and Leclercq (1994) who noted that dietary protein has very little influence on feed intake.

Continuous multi-phase feeding resulted in higher fecal nitrogen content versus single-phase feeding in the first and second week but decreased for the third week (Figure 3-4 and Table 3-6). This was to be expected based on the protein content of the diets being fed. According to Verstegen (1995), efficiency of dietary nitrogen utilization varies dependent upon the degree of protein N digestibility, amino acid N absorption or availability, metabolic N demands, and dietary amino acid imbalance. The efficiency of nitrogen utilization decreases as maintenance requirements for nitrogen increases due to larger body size (Ferket, 1999).

Overall, continuous multi-phase feeding resulted in little improvement with respect to lowering fecal nitrogen content. It should be noted that no attempt was made to acidify the feces thus one can presume total nitrogen excretion was higher than what was measured due to some loss of ammonia.

As with the other variables measured in this study, feed cost per kilogram of gain between the multi-phase and single-phase feeding program, was not significantly different (Table 3-7). Pope and Emmert (2001) reported there was a small reduction feed cost associated with multi-phase feeding.

TABLE 3-7. Effect of multi-phase feeding on feed cost per kg of gain

Experiment	Feed cost per kg of gain ($US) Multi-phase	Single-phase	[Multi-phase] – [Single-phase]
1	0.251±0.07	0.238±0.08	0.013
2	0.218±0.06	0.227±0.04	-0.009

Values are mean ± SEM.
Diet cost ($/kg) experiment 1 multi-phase: $0.161, single-phase: $0.164. Experiment 2 multi-phase: $0.162, single-phase: $0.165.

In summary, compared to single-phase feeding during a 3-week starter period, multi-phase feeding as described herein did little to improve growth and feed to gain ratio or reduce fecal nitrogen content. The increased capital cost of implementing a multi-phase feeding system using the linear dietary blend described in this study are not justified by any improvement in chick performance.

CHAPTER IV

EFFECT OF INTENSIVE MULTI-PHASE FEEDING ON BROILER PERFORMANCE AND NITROGEN EXCRETION

INTRODUCTION

Increasingly, the broiler industry is obliged to reduce the negative effects of intensive production systems on the environment. Until recently consideration of the response of animals to nutrient supply was confined to maximizing the efficiency of weight gain and less attention was paid to reducing the output of nitrogenous materials in the animal excretion. According to Morse (1995) the excretion of N originating from dietary protein is the most prevalent form of N pollution resulting from animal production. Moreover, nutrient management planning can be a key component of protecting the environment (Fox, 2001). One nutritional approach to reducing nutrient excretion is to precision feed diets formulated to exactly meet the bird's requirement on any given day. Unfortunately, accurately knowing an animal's specific nutrient requirements on any given day is difficult because nutritional requirements are moving targets influenced by many factors such as yearly changes in genetic characteristics of the animal in question (Ferket et al, 2002). There are several "references and models" available to estimate nutritional requirements. The nutritional requirements advocated for broilers by the NRC (1994) are largely based on experimentation conducted several decades ago and defined under laboratory-type conditions where animals are well cared for and the environmental conditions are maintained as close to optimum as possible. In an attempt to accommodate expected needs associated with additional growth, under field conditions, the commercial broiler industry typically employs higher requirements for certain nutrients, such as essential amino acids (Agri Stats, 2001).

Most commercial broiler grow out programs used in the United States employ four different diets: Starter, Grower, Withdrawal 1 and Withdrawal 2 (Agri Stats, 2001). Because protein or amino acid requirements gradually change as age increases, when a single diet is used for a long time period, broilers are either under- or over-supplied with nutrients throughout the majority of the growth period. According to Belyavin (1999) one approach to overcome this problem is to feed more diets throughout the growing period. A strategy to match feed composition to the broilers nutritional requirements during progressive periods of growth is called phase feeding or multi-phase feeding. Multi-phase feedings are designed to meet the bird's nutritional needs at specific points in the life cycle.

Nutritional management can also be used as a tool to help control environmental pollution. Theoretically, changing the diet several times in order to better match protein requirements will improve efficiency of protein utilization and thereby reduce environmental pollution. In swine, multi-phase feeding has been used to decrease nitrogen excretion without sacrificing growth performance (Boisen et al., 1991). Koch (1990) calculated nitrogen and phosphorus excretions could be reduced by 13% by utilizing two grower-finisher diets versus a single diet. From a management perspective, it is probably not practical to send a lot of diets from the feedmill to the chicken house. Theoretically, two different diets could be blended together daily to more precisely meet the bird's requirements as the feed is being delivered directly to the chicken houses. Two feed bins and a proportioning system would be required at each chicken house. Luckily the majority of poultry houses in the US are already equipped with two external feed bins. The objective of this study was to compare broiler performance using a traditional industry-type four-phase feeding program with an intensive multi-phase feeding program in which two diets are blended every three days for a seven week grow out period. Fecal nitrogen excretion and 7-week nitrogen retention was also evaluated.

MATERIALS AND METHODS

Two experiments were conducted to evaluate rearing programs utilizing male broiler chicks of a Ross x Ross strain. In Experiment 1, 60 day-old broilers were randomly placed in 30 separate battery brooder pens (2 chicks per pen). Treatments consisted of a four-phase feeding program and multi-phase feeding program in which the diets were changed every three days over a 49 day growing period. Treatment 1 consisted of an industry standard four-phase program: starter diet, 0 to 3 weeks; grower, 3 to 5 weeks; withdrawal 1, 5 to 6 weeks and withdrawal 2, 6 to 7 weeks. Nutrient compositions were set based on commercial industry averages (Agri Stats, 2001) (Table 4-1). In treatments 2 and 3, the diets were changed every three days using a linear blend of starter, grower and finisher diets. Nutrient compositions for diets in treatment 2 were based on the Agri Stats data (Table 4-2) and linear blends were made based on treatment 1 nutrient content for day 11, 27 and 43 (see Appendix B). Treatment 3 was based on computer modeling using Broiler Growth Model 5.1 (EFG Natal®) with slight modification in that diets were blended linearly similar to treatment 2 (Table 4-3).

TABLE 4-1. Composition of treatment 1 diets (experiments 1 and 2)

Ingredients	Starter Weeks 1-3	Grower Weeks 4-5	Withdrawal 1 Week 6	Withdrawal 2 Week 7
Corn	56.28	61.23	63.07	63.15
Dehulled Soybean Meal	36.96	31.82	30.29	30.30
DL- Methionine	0.21	0.21	0.10	0.07
L-Lysine HCl	-	-	-	-
Fat, A&V Blend	2.98	3.38	3.60	3.90
Limestone	1.10	1.05	0.97	0.99
Mono-dicalcium PO4	1.64	1.46	1.26	1.04
Salt	0.46	0.46	0.33	0.26
Trace Minerals[1]	0.05	0.05	0.05	0.05
Vitamin premix[2]	0.25	0.25	0.25	0.25
Coban 60	0.08	0.08	0.08	-
Calculated nutrient content (%)				
Poultry ME (Kcal/kg)	3063	3140	3180	3208
Crude Protein	22.83	20.76	20.11	20.10
Lysine	1.24	1.10	1.06	1.06
Arginine	1.50	1.34	1.29	1.29
Methionine + cysine	0.92	0.87	0.75	0.72
Tryptophan	0.31	0.27	0.26	0.26
Threonine	0.85	0.77	0.75	0.75
Calcium	0.89	0.82	0.74	0.70
Non-phytin Phosphorus	0.43	0.39	0.35	0.31

[1]Trace mineral premix provided 149.6 mg manganese, 125.4 mg zinc, 16.5 mg iron, 1.7 mg copper, 1.05 mg iodine, 0.25 mg selenium, a minimum of 6.27 mg calcium and a maximum of 8.69 mg calcium per kg of diet.

[2]Vitamin premix provided 11,023 IU vitamin A, 3,858 IU vitamin D, 46 IU vitamin E, 0.0165 mg B_{12}, 5.845 mg riboflavin, 45.93 mg niacin, 477.67 mg choline, 20.21 mg d-pantothenic acid, 1.47 mg menadione, 1.75 mg folic acid, 2.94 mg thiamine, 7.17 mg pyridoxine, 0.55 mg biotin per kg diet.

TABLE 4-2. Composition of treatment 2 blended diets (experiments 1 and 2)

Ingredients	Diet A (Weeks 1-4)	Diet B (Weeks 1-7)	Diet C (Weeks 4-7)
Corn	53.37	60.28	62.80
Dehulled Soybean Meal	39.57	33.36	30.36
DL- Methionine	0.21	0.20	0.06
L-Lysine HCl	-	-	-
Fat, A&V Blend	314	2.75	4.08
Limestone	1.13	1.07	1.00
Mono-dicalcium PO4	1.73	1.50	0.93
Salt	0.46	0.46	0.46
Trace Minerals[1]	0.05	0.05	0.05
Vitamin premix[2]	0.25	0.25	0.25
Coban 60	0.08	0.08	-
	Calculated nutrient content (%)		
ME (Kcal/kg)	3090	3135	3214
Crude Protein	23.85	21.42	20.10
Lysine	1.31	1.14	1.06
Arginine	1.58	1.39	1.30
Methionine + cystine	0.95	0.88	0.71
Tryptophan	0.32	0.28	0.26
Threonine	0.89	0.80	0.75
Calcium	0.93	0.84	0.68
Non-phytin Phosphorus	0.45	0.40	0.29

[1]Trace mineral premix provided 149.6 mg manganese, 125.4 mg zinc, 16.5 mg iron, 1.7 mg copper, 1.05 mg iodine, 0.25 mg selenium, a minimum of 6.27 mg calcium and a maximum of 8.69 mg calcium per kg of diet.

[2]Vitamin premix provided 11,023 IU vitamin A, 3,858 IU vitamin D, 46 IU vitamin E, 0.0165 mg B_{12}, 5.845 mg riboflavin, 45.93 mg niacin, 477.67 mg choline, 20.21 mg d-pantothenic acid, 1.47 mg menadione, 1.75 mg folic acid, 2.94 mg thiamine, 7.17 mg pyridoxine, 0.55 mg biotin per kg diet.

TABLE 4-3. Composition of treatment 3 blended diets (experiments 1 and 2)

Ingredients	Diet A (Weeks 1-4)	Diet B (Weeks 1-7)	Diet C (Weeks 4-7)
Corn	47.48	60.61	61.52
Dehulled Soybean Meal	43.44	31.76	30.49
DL- Methionine	0.10	0.05	-
L-Lysine HCl	0.29	0.10	-
Fat, A&V Blend	5.06	4.09	4.67
Limestone	1.12	1.07	1.08
Mono-dicalcium PO4	1.76	1.47	1.48
Salt	0.46	0.46	0.46
Trace Minerals[1]	0.05	0.05	0.05
Vitamin premix[2]	0.25	0.25	0.25
Coban 60	0.08	0.07	-
Calculated nutrient content (%)			
ME (Kcal/kg)	3117	3179	3225
Crude Protein	25.38	20.69	20.02
Lysine	1.64	1.18	1.06
Arginine	1.69	1.34	1.29
Methionine + cystine	0.82	0.71	0.65
Tryptophan	0.35	0.27	0.14
Threonine	0.95	0.77	0.75
Calcium	0.94	0.83	0.83
Non-phytin Phosphorus	0.46	0.39	0.39

[1]Trace mineral premix provided 149.6 mg manganese, 125.4 mg zinc, 16.5 mg iron, 1.7 mg copper, 1.05 mg iodine, 0.25 mg selenium, a minimum of 6.27 mg calcium and a maximum of 8.69 mg calcium per kg of diet.

[2]Vitamin premix provided 11,023 IU vitamin A, 3,858 IU vitamin D, 46 IU vitamin E, 0.0165 mg B_{12}, 5.845 mg riboflavin, 45.93 mg niacin, 477.67 mg choline, 20.21 mg d-pantothenic acid, 1.47 mg menadione, 1.75 mg folic acid, 2.94 mg thiamine, 7.17 mg pyridoxine, 0.55 mg biotin per kg diet.

The EFG model calculated nutrient requirements based on a modern broiler breed with a stocking density of 8 birds/m^2, and temperature decreasing from 31 ^oC according to breeder recommendations (see appendix B for predicted nutrient requirement). For the intensive multi-phase feeding treatments, the diets were created by blending 2 basal diets. Diet A was reduced from high proportion to low proportion and Diet B was increased from low to high proportion according to appropriate calculations. There were 10 replicate Petersime brooder pens per treatment. All diets were provided ad libitum in the mash form. Uneaten feed was collected and weighed every three days. Water was freely available throughout the study and the light remained on 24 hours per day. The birds were weighed by pen every day. A metal tray was placed under each pen, and the excreta were collected and weighed daily at approximately 10:30 A.M. No attempt was made to acidify the collected excreta. Uneaten feed was discarded and replaced with fresh feed daily. Temperature was gradually decreased from 28 to 20^oC over the course of the experiment. All samples were kept in a freezer until they could be analyzed for nitrogen and dry matter. Body composition data were obtained from 10 randomly selected chicks per treatment. Birds were killed by CO_2 inhalation and immediately frozen at –4^oC. After thawing, frozen chicks were steamed for 70 minutes, cooled for 4 hours and cut into small pieces with a knife. These pieces were then ground three times with a Hobart® mixer fitted with a grinder attachment. The first grinding utilized a 0.95 cm die, while the second and third grinding used a 0.32 cm die. Nitrogen analyses of feed, feces and whole ground chick was performed using a LECO™ combustion nitrogen analyzer.

Experiment 2 was similar to experiment 1, with a few exceptions. A total of 540 day-old male broilers were randomly placed in 36 floor pens (1.8 x 2.0 m) with pine shavings litter (15 birds per pen). All diets were fed ad libitum and remaining feed from all treatments was discarded every three days after weighing both birds and remaining feed. The birds and uneaten feed were also weighed by pen every 7 days to conform to traditional weigh periods. Data were not collected for nitrogen retention or excretion in this study, which were designed primarily to assess performance on littered floor pens.

STATISTICAL ANALYSIS

Experiment 1 was analyzed by one-way ANOVA, while experiment 2 was first analyzed by two-way ANOVA for a randomized block design (SAS, 1996). Interaction with block effects were not significant so experiment 2 was reanalyzed by one-way ANOVA. When a significant main effect was detected, differences among treatment means were established using the Duncans multiple range test procedure. Statements of significance were based on $P \leq 0.05$.

RESULTS AND DISCUSSION

Experiment 1

Experiment 1 was conducted to evaluate the effect of intensive multi-phase feeding on broiler performance and nitrogen excretion. All birds were weighed every three days and every week. The results showed there was no significant effect of multi-phase feeding on the body weight gain in weeks 1 and 2 (Table 4-4).

This finding was consistent with the results of Warren and Emmert (2000) who reported multi-phase feeding had no significant effect during this early period because feed consumption was relatively low. However, in weeks 3 and 4, birds on both intensive multi-phase feeding programs had significantly higher body weight gain compared to birds on the four-phase feeding program. Week 3 may represent a period of over-feeding for the industry type four phase feeding program if one presumes the starter diet is based on day 11 requirements while week 4 may represent a period of under feeding as the starter diet was switched to the grower diet. One would thus not necessarily expect to see reduced body weight at this time.

TABLE 4-4. Cumulative weight gain and feed consumption (experiment 1)

Week	Weight gain (g)			Feed consumption (g)		
	Industry Four-phase	Industry Multi-phase	EFG Multi-phase	Industry Four-phase	Industry Multi-phase	EFG Multi-phase
1	101±4	101±4	102±4	122±6	121±5	121±4
2	330±7	334±5	337±4	480±11	480±11	479±11
3	686±7[a]	697±6[b]	703±6[b]	1095±27	1078±24	1103±23
4	1226±14[a]	1255±12[b]	1261±12[b]	2004±48	2011±29	2016±24
5	1855±37	1864±31	1874±29	3270±67	3253±60	3277±61
6	2303±34	2311±38	2331±44	4409±85	4419±87	4427±64
7	2994±56	3012±53	3023±53	5912±120	5909±15	5920±128

[a,b]Different superscripts within a row indicate significant differences ($P < 0.05$).

However, it should be noted that birds on the four-phase feeding program also weighed numerically less at the end of week 2. This difference appear to have just been magnified by weeks 3 and 4. By week 5 the four-phase birds had statistically caught up to the intensive multi-phase birds, although they still lagged numerically for the remained of the study. The four-phase birds still weighed only 29 g less than the EFG birds by the end of week 7 of the study. Similar compensatory growth was reported by Moran (1979). In his experiment broiler male chickens were provided with a 24% starter diet (0-2 weeks) followed by grower diets containing 24, 22 or 20% protein (2-5 weeks) and finally a finisher diet (5-7 weeks) containing 20% protein. Although body weights at 5 weeks of age were significantly below the control birds, no differences were observed by week 7.

There was no significant effect of intensive multi-phase feeding on cumulative feed consumption from week 1 to week 7 (Table 4-4). This result were agrees with other reports on the performance of broilers fed multi-phase diets (Warren and Emmert, 2000; Pope and Emmert 2001; Pope et al, 2002). According to Larbier and Leclercq (1994) energy is the most important determinant of feed intake. Energy contents of the diets used in this study were quite similar to one another.

Intensive multi-phase feeding had no effect on feed to gain ratio from week 1 to week 2, but there was a significant effect by week 3 and week 4 (Table 4-5). Birds receiving the intensive multi-phase feeding program had significantly better cumulative feed to gain ratios compared to those receiving the four-phase feeding program. As with cumulative weight gain, significant differences in feed to gain ratio disappeared by week 4 of the study. There was no treatment affect on dry matter, whole body nitrogen content (Table 4-6), and nitrogen intake, fecal nitrogen content, or 7-week nitrogen retention (Table 4-7).

TABLE 4-5. Cumulative feed to gain ratio (experiment 1)

Week	Treatment		
	Industry Four-Phase	Industry Multi-phase	EFG Multi-Phase
1	1.21±0.02	1.20±0.02	1.19±0.04
2	1.46±0.03	1.44±0.03	1.45±0.03
3	1.60±0.04 [a]	1.55±0.06 [b]	1.57±0.03 [b]
4	1.64±0.05 [a]	1.60±0.04 [b]	1.60±0.04 [b]
5	1.76±0.06	1.75±0.05	1.75±0.03
6	1.91±0.06	1.90±0.08	1.90±0.06
7	1.97±0.07	1.96±0.06	1.96±0.07

[a,b]Different superscripts within a row indicate significant differences ($P < 0.05$)

The lack of significant differences on growth performance, whole-body composition, and N retention suggest that the diets and feeding schemes provided sufficient nutrients for reasonable growth.

TABLE 4-6. Whole body analysis (experiment 1)

	Treatment		
	Industry Four-Phase	Industry Multi-phase	EFG Multi-Phase
DM (%)	30.4±0.4	30.1±0.2	30.6±0.4
Nitrogen (%)	8.50±0.2	8.58±0.1	8.27±0.3

TABLE 4-7. Effect of intensive multi-phase feeding on average daily nitrogen intake and fecal nitrogen content (experiment 1)

Days	Nitrogen intake (g/bird/d)				Fecal nitrogen content (g/bird/d)			
	Industry Four-phase	Industry Multi-phase	EFG Multi-phase	PSEM[1]	Industry Four-Phase	Industry Multi-phase	EFG Multi-phase	PSEM[1]
1-6	0.55[a]	0.58[b]	0.59[b]	0.01	0.17	0.17	0.18	0.01
7-12	1.58[a]	1.57[b]	1.70[b]	0.02	0.61	0.60	0.66	0.02
3-18	2.71	2.67	2.70	0.04	1.22	1.21	1.21	0.02
19-24	3.68	3.57	3.56	0.06	1.75	1.70	1.69	0.03
25-30	4.74	4.84	4.62	0.08	2.70	2.78	2.68	0.04
31-36	6.31	6.12	6.07	0.08	3.98	3.90	3.84	0.06
37-42	5.41	5.46	5.55	0.07	3.63	3.63	3.67	0.05
43-49	6.70	6.39	6.51	0.10	4.69	4.46	4.55	0.05

[a,b]Different superscripts within a row indicate significant differences ($P < 0.05$).
[1]PSEM = Pooled standard error of the mean.

In numerical terms total N intake of the standard four-phase feeding program was higher than either of the intensive multi-phase feeding programs (Table 4-8). Approximately 17% of nitrogen intake for all 3 treatments was unaccounted for and presumably lost to the atmosphere as ammonia (Table 4-8).

TABLE 4-8. Nitrogen intake, excretion, retention and loss during 7 weeks (experiment 1)

	Treatment		
	Industry Four-Phase	Industry Multi-phase	EFG Multi-phase
N intake, g/bird	190.1±4.0	187.2±3.2	187.8±5.2
N excretion, g/bird	78.8±4.2	77.5±5.1	77.6±2.3
N excretion, % of intake	41.5±1.3	41.4±1.2	41.3±2.2
N retention, g/bird	78.4±3.2	78.8±2.1	77.5±4.3
N retention, % of intake	41.2±1.9	42.1±1.6	41.3±1.7
N lost, g/bird	32.3±1.2	30.9±2.1	32.7±2.3
N lost, % of intake	17.0±1.2	16.5±1.9	17.4±1.3

Bregendahl et al. (2002) compared nitrogen retention and excretion in the broilers fed diets with low (19 and 20%) and standard (23%) crude protein and found N excretion directly correlated with N intake. Unfortunately, neither multi-phase treatment resulted in a significant reduction of nitrogen lost to the environment in this study.

Experiment 2

Experiment 2 was similar Experiment 1 but it measured performance under conditions more closely resembling the commercial industry. Unlike experiment 1, there were no differences in cumulative body weight gain by week 3 and 4 (Table 4-9) However, cumulative weight gains were significantly higher for both the intensive multi-phase feeding and the four-phase feeding treatment at weeks 5 and 6. By week 7 however, there were no significant differences between the intensive multi-phase feeding programs and the four-phase program

TABLE 4-9. Cumulative weight gain and feed consumption (experiment 2)

Week	Weight gain (g)			Feed consumption (g)		
	Industry Four-phase	Industry Multi-phase	EFG Multi-phase	Industry Four-phase	Industry Multi-phase	EFG Multi-phase
1	115±6	123±2	121±2	140±2	149±3	148±2
2	366±5	383±7	382±6	486±6	500±6	508±6
3	753±10	782±12	782±15	1084±20	1124±15	1119±13
4	1238±13	1263±20	1248.4±24	1989±35	2036±29	2006±23
5	1841±19[a]	1875±18 [b]	1860±19[b]	3254±40	3188±49	3146±39
6	2330±27 [a]	2415±39 [b]	2388±37 [b]	4407±53	4347±81	4303±63
7	2671±33	2709±51	2746±37	5489±61	5419±98	5405±24.

[a,b]Different superscripts within a row indicate significant differences ($P < 0.05$).

Compared to experiment 1, cumulative body weight gain in this experiment was lower. This is most likely an ambient temperature affect as experiment 2 was conducted in the summer. For experiment 1, birds were maintained in an air conditioner room were we could adjust temperature as needed for optimum growth. The same pattern for cumulative feed to gain ratio observed in experiment 1 was also observed for experiment 2 except that these differences occurred during weeks 5 and 6 rather than weeks 3 and 4 (Table 4-10).

TABLE 4-10. Cumulative feed to gain ratio (experiment 2)

Week	Treatment		
	Industry Four-phase	Industry Multi-phase	EFG Multi-phase
1	1.21±0.02	1.20±0.02	1.19±0.04
2	1.46±0.03	1.44±0.03	1.45±0.03
3	1.60±0.02 [a]	1.55±0.02 [b]	1.57±0.03 [b]
4	1.64±0.02 [a]	1.60±0.02 [b]	1.60±0.02 [b]
5	1.76±0.05	1.75±0.05	1.75±0.03
6	1.91±0.06	1.90±0.08	1.90±0.06
7	1.97±0.07	1.96±0.06	1.96±0.07

[a,b]Different superscripts within a row indicate significant differences ($P<0.05$).

The effects on feed to gain ratio appeared primarily due to differences in body weight gain rather than differences in feed consumption which was not significantly different. Feed cost associated with gain for the intensive multi-phase feeding programs were lower versus the four-phase feeding program (Table 4-11). This finding agrees with Pope and Emmert (2001) who reported multi-phase feeding reduced cost during the grower and finisher periods.

Overall mortality rate in both experiments was very low (less than 3%) and there were no significant differences among treatment groups throughout the study period.

The results of these two experiments indicate that intensive multi-phase feeding does not have a significantly effect on performance. However, economic analysis indicated that intensive multi-phase feeding program could potentially lower feed costs per/kg of gain. However, the economic feasibility of intensive multi-phase feeding also depends the cost associated with both feed mixing and delivery which were not addressed in these studies and presumably would be quite high.

TABLE 4-11. Effect of multi-phase feeding on feed cost per kg of gain (experiment 1 and experiment 2)

Week	Feed cost per kg of gain ($US)		
	Industry Four-phase	Industry Multi-phase	EFG Multi-phase
Exp. 1	0.40±0.01 [a]	0.37±0.01 [b]	0.36±0.02 [b]
Exp. 2	0.43±0.02 [a]	0.39±0.01 [b]	0.38±0.01 [b]

[a,b]Different superscripts within a row indicate significant differences ($P < 0.05$).
Average diet cost ($/kg): Industry four-phase, $0.147. Industry multi-phase, $0.145.
EFG multi-phase, $0.150.

CHAPTER V

CONCLUSION

Environmental concerns over pollution resulting from intensive animal production are likely to be prevalent for the foreseeable future. These concerns deal primarily with excessive nitrogen and phosphorus contamination of our streams, rivers and watersheds. Two of the more obvious solutions to the problem are to (1) scavenge or trap the pollutants before they can do damage to the countries water and air resources and, (2) to improve the efficiency of utilization of nutrients by the animal it self thereby limiting the source of the pollutants. This dissertation focused on the second solution, improving efficiency of nutrient utilization, primarily with regard to nitrogen retention.

Traditional poultry feeding protocols call for 3-4 diets to be fed over the productive lifetime of a broiler chicken. This multi-phase approach to rearing is based on the realization that the birds specific nutrient requirements theoretically change on a daily basis as it is actively growing and changing its whole body nutrient composition. For practical reasons dealing with both feed manufacture and delivery to the grower facility, it has not been economically feasible to feed more than four or so distinct diets over the 6-week growing period.

In recent years, most broiler grower houses have been equipped with two feed bins and essentially all new facilities are built with two external feed bins. This strategy ensures against feed outages and simplifies or provides more flexibility with respect to feed delivery. Given this fact, it is at least theoretically feasible to deliver two distinct diets to a facility and then using the appropriate hardware blend those diets together in such a way to precisely meet the birds requirements at all times throughout the rearing period. At least one England based company, Flockman ™ , has developed the equipment to essentially do this by blending a cereal grain with a concentrate as the feed is being delivered directly to the birds in the grower facility. Such delivery systems are obviously much more costly than those simple systems used throughout the United States and adoption of such a system here would be depend both on significantly improved productivity as well as reduced environmental pollution.

These ideas were evaluated herein by conducting a series of four distinct experiments. Experiments 1 and 2 dealt with the relatively short 3-week starter period utilizing commercial broilers, raised in non-commercial Petersime type battery brooders. Experiments 3 and 4 dealt with a traditional growing period of 7weeks using both battery brooder reared birds and birds reared in floor pens on pine shaving litter.

For experiments 1 and 2, a continuous multi-phase feeding program in which new distinct diets were introduced to the birds on a daily basis, was compared to single-phase program over the entire 3-week growing period. Surprisingly, we were not able to detect any significant difference in either broiler performance or fecal nitrogen content between the two feeding protocols. Apparently these young broilers are phenotypically robust enough to adopt to “less precise” diets without significant impact on their overall growth and efficiency of feed utilization. It is also possible that the linear blends used for the continuous multi-phase protocol were not “precise” enough relative to the birds true nutrient requirement on any given day. This is particularly true for Experiment 1 where it became obvious the birds were selectively picking out the corn.

Experiment 3 focused on nitrogen balance and experiment 4 dealt primarily with production issues over a fairly typical 7-week production period. In contrast to experiments 1 and 2, intensive multi-phase feeding did result in significantly improved feed to gain ratios during both weeks 3 and 4 of the study. The intensive multi-phase diets utilized in experiments 3 and 4 were somewhat different from those used in experiments1 and 2 and may have affected this observation. Interestingly, a similar observation was made for experiment 4, only the improved feed to gain ratio occurred later during weeks 5 and 6 of the study. It is not clear why this difference in timing occurred since the diets used for experiment 3 and 4 were identical in every respect. It was noted that the birds grew at a slightly slower rate during experiment 4, most probably due to the high ambient temperature of the summer grow out period. As in experiment 1 and 2, the intensive multi-phase rearing program did not significantly affect nitrogen retention nor excretion.

Perhaps the observation of most interest to the commercial poultry industry is feed cost per pound of gain. Since feed cost typically account for approximately 70% of total production cost, this is a critical number with respect to profitability. Our data suggest continuous or intensive multi-phase feeding can potentially lower feed cost per pound of gain when evaluated independently from the capital equipment cost associated with such a protocol in the “real world”. Given the added cost of implementing a practical continuous multi-phase feeding system it is unlikely those small gains could be economically justified.

Based on the data presented here, continuous multi-phase feeding can not be justified either in terms of productive performance or significant reductions in nitrogen excretion by broiler chickens. Perhaps, a nutrient modeling system, such as EFG (Natal) in future years may achieve the precision needed to successfully implement such a system that remains for future researches to test and evaluated.

REFERENCES

AAFCO. 2001. Official publications. Association of American Feed Control Officials, Inc., Oxford, IN.

Agri Stats. 2001. Annual Live Production. Agri Stats, Inc., Fort Wayne, IN.

Armstrong, H. 1993. Nutritional implications of expanded feed. Feed Mix 1:26-27.

Austic, R. E. 1994. Update on amino acid requirements and ratios for broilers. Pages 115-120 in Proceedings of the Maryland Nutrition Conference. College Park, MD.

Baker, D. H., and Y. Han. 1994. Ideal amino acid profile for chicks during the first three weeks post hatching. Poult. Sci. 73:1441-1447.

Bell, A. 1998. How many phases should you feed? Pork, 98, May: 34-38.

Belyavin, C. G. 1999. Nutrition management of broiler programs. Pages 93-105 in Recent Advances in Animal Nutrition. Nottingham University Press, Nottingham, UK.

Beyer, R. S., J. S. Moritz, K. J. Wilson, and K. R. Cramer. 2001. Feed processing, feed form affect animal performance. Feedstuffs 73:10-13.

Black, J. L., and C. F. M. De Lange. 1995. Introduction to the principles of nutrient partitioning for growth. Pages 59-75 in Modeling Growth in the Pig. P. J. Moughan, M. Verstegen, and M. I. Visser-Reyneveld, ed. Wageningen Press, Wageningen, Netherlands.

Boisen, S., J. A. Fernandez, and A. Madsen. 1991. Studies on ideal protein requirement of pigs from 20 to 95 kg live weight. Page 299 in Proceedings of the Sixth International Symposium on Protein Metabolism and Nutrition, Herning, Denmark.

Boisen, S., T. Hvelplund, and M. R. Weisbjerg. 2000. Ideal amino acid profiles as basis for feed protein evaluation. Livestock Prod. Sci. 64:239-251.

Bregendahl, K., J. L. Sell, and D. R. Zimmerman. 2002. Effect of low-protein diets on growth performance and body composition of broiler chicks. Poult. Sci. 81:1156-1167.

Bruce, J. M. 1981. Ventilation and temperature control criteria for pigs. Pages 29-37 in Environmental Aspects of Housing for Animal Production. J.A. Clark, ed. Butterworths, London.

Bundy, D. S. 1992. Odor issue with wastes. Pages 27-42 in Proceedings of the National Livestock, Poultry and Aquaculture Waste Management Conference. American Society of Agricultural Engineers, St. Joseph, MI.

Burton, D. L., and E. G. Beauchamp. 1986. Nitrogen losses from swine housings. Agric. Wastes 15:59-74.

Buttery, P. J., and J. P. F. D'Mello. 1994. Amino acid metabolism in farm animals: an overview. Pages 1-9 in Amino Acids in Farm Animal Nutrition. J. P. F. D'Mello, ed. CAB International, Guilford, UK.

Camire, M. E. 2000. Chemical and nutritional changes in food during extrusion. Pages 127-147 in Extruders in Food Applications. M. N. Riaz, ed. Technomic Publishing, Lancaster, PA.

Campbell, J. W. 1995. Excretory nitrogen metabolism in reptiles and birds. Pages 147-171 in Nitrogen Metabolism and Excretion. P. J Walsh and P. Wright, ed. CRC Press, NY.

Chescheir, G. M., P. W. Weterman, and L. M. Safley. 1986. Laboratory methods for estimating available nitrogen in manure and sludge. Agric. Wastes 18:175-195.

Classen, H. L., and J. P. Stevens. 1995. Nutrition and growth. Pages 79-95 in World Animal Science. P. Hunton, ed. Elsevier, Amsterdam, Netherlands.

Collins, E. R., Jr., J. C. Barker, L. E. Carr, H. L. Brodie, and J. H. Martin, Jr. 1999. Poultry Waste Management Handbook. NRAES Cooperative Extension, Ithaca, NY.

Copeland, C., and J. Zinn. 1998. Animal waste management and the environment: background for current issues. Congressional Research Service. The Committee for the National Institute for the Environment, Washington, DC.

Cowan, P. J., and W. Michie. 1978. Environmental temperature and choice feeding of the broiler. Br. J. Nutr. 40:311-315.

De Boer, I. J., P. L. Van Der Togt, M. Grossman, and R. P. Kwakkel. 2000. Nutrient flows for poultry production in The Netherlands. Poult. Sci. 79:172-179.

De Lange, C. F. M. 1997. Dietary means to reduce the contributions of pigs to environmental pollution. Pages 25-36 in Proceedings of the Swine Production and Environment Seminar, Shakespeare, Ontario.

De Rham, O., and T. Jost. 1979. Phytate protein interactions in soybean extracts and low phytate soy protein products. J. Food Sci. 44:596-600.

D'Mello, J. P. F. 1994. Response of growing poultry to amino acids. Pages 205-239 in Amino Acids in Farm Animal Nutrition. J. P. F. D'Mello, ed. CAB International, Guilford, UK.

Emmans, G. C. 1987. Growth, body composition and feed intake. World's Poult. Sci. J. 43:208-227.

Ferguson, N. S., R. S. Gates, J. L. Taraba, A. H. Cantor, A. J. Pescatore, M. J. Ford, and D. J. Burnham. 1998. The effect of dietary crude protein on growth, ammonia concentration, and litter composition in broilers. Poult. Sci. 77:1481-1487.

Ferket, P. R. 1999. Nutritional applications to reduce mineral emission from production animals. Pages 74-86 in Proceedings of the Animal Waste Management Symposium. North Carolina State University, University Graphics, Raleigh, NC.

Ferket, P. R., E. van Heugten, T. A. van Kempen, and R. Angel. 2002. Nutritional strategies to reduce environmental emissions from nonruminants. J. Anim. Sci. 80:168-182.

Fisher, C. 1994. Responses of laying hens to amino acids. Pages 245-276 in Amino Acids in Farm Animal Nutrition. J. P. F. D'Mello, ed. CAB International, Edinburgh, UK.

Flockman. Layout of flockman on the farm. Available: www.flockman.com/Layout.htm [Accessed: November 2003]

Fox, D. G. 2001. Scientific Advances in Animal Nutrition. National Academy Press, Washington, DC.

Gilham, R. W., and L. R. Webber. 1969. Nitrogen contamination of ground water by barnyard leachates. Water Pol. Cont. Fed. J. 41:1752-1762.

Goldstein, D. L., and E. Skadhauge. 2000. Renal and external regulation of body fluid composition. Pages 265-291 in Sturkies Avian Physiology. 5th ed. G. C. Whittow, ed. Academic Press, San Diego, CA.

Guray, E., N. Ocak, E. Ozturk, and A. Ozdas. 2003. Effect of different choice feeding methods based on whole wheat on performance of male broiler chickens. Anim. Feed Sci. Technol. 105:131-138.

Han, Y., and D. H. Baker. 1991. Lysine requirements of fast and slow growing broiler chicks. Poult. Sci. 70:2108-2114.

Han, Y., and D. H. Baker. 1993. Effects of sex, heat stress, body weight and genetic strain on the dietary lysine requirement of broiler chicks. Poult. Sci. 72:701-708.

Han, Y., H. Suzuki, C. M. Parsons, and D. H. Baker. 1992. Amino acid fortification of a low-protein corn and soybean meal diet for chicks. Poult. Sci. 71:1168-1178.

Hessing, M., H. van Laarhoven, J. A. Rooke, and A. Morgan. 1996. Quality of soybean meal and the effect of microbial enzymes in degrading soy antinutritional compounds. Pages 8-13 in the 2nd International Soybean Processing and Utilization Conference. Bangkok, Thailand.

Houlihan, D. F., C. G. Carter, and I. D. McCarthy. 1995. Protein turnover in animals. Pages 1-26 in Nitrogen Metabolism and Excretion. P. J. Walsh and P. Wright, ed. CRC Press, New York.

Huber, G. R. 2000. Twin-screw extruder. Pages 81-113 in Extruders in Food Applications. M. N. Riaz, ed. Technomic Publishing, Lancaster, PA.

Kerr, B. J., and R. A. Easter. 1995. Effect of feeding reduced protein, amino acid-supplemented diets on nitrogen and energy balance in grower pigs. J. Anim. Sci. 73:3000-3008.

Kim, J. H., H. D. Hancock, R. H. Hines, and M. S. Kang. 1994. Roasting and extruding affect ileal digestibility of nutrients from soybeans in growing and finishing pigs. Kansas State University, Manhattan, KS.

Kim, K. I., I. McMillan, and H. S. Bayley. 1983. Determination of amino acid requirements of young pigs using an indicator amino acid. Br. J. Nutr. 50:369-382.

Kim, Y. G., J. Jin, J. D. Kim, I. S. Shin, and K. Han. 2000. Effect of phase feeding on growth performance, nutrient digestibility and nutrient excretion and carcass characteristic of finishing barrow and gilts. Asian-Aus. J. Anim. Sci. 6:802-810.

Koch, F. 1990. Amino acid formulation to improve carcass quality and limit nitrogen waste. Pages 76-95 in Proceedings of the Caroline Swine Nutrition Conference, Raleigh, NC.

Kornegay, E. T. 1996. Nutritional, environmental and economic considerations for using phytase in pig and poultry diets. Pages 277-295 in Nutrient Management of Food Animals to Enhance and Protect the Environment. E. T. Kornegay, ed. CRC Press, New York.

Kornegay, E. T., and M. Verstegen. 2001. Swine nutrition and pollution and odor control. Pages 609-630 in Swine Nutrition. A. J. Lewis and L. L. Southern, ed. CRC Press, Boca Raton, FL.

Larbier, M. 1987. Protein nutrition of non-ruminants. Pages 14-18 in Feeding of Non Ruminant Livestock. J. Wiseman, ed. Butterworths, London.

Larbier, M., and B. Leclercq. 1994. Nutrition and Feeding of Poultry. Nottingham University Press, Loughborough, Leicestershire, UK.

Leeson, S., and J. D. Summers. 2001. Nutrition of the Chicken. 4th ed. University Books, Guelph, Ontario, Canada.

Lilja, C. 1983. A comparative study of postnatal growth and organ development in some species of birds. Growth 47:317-339.

Ling, B., R. Angel, T. J. Applegate, N. G. Zimmerman, and A. S. Dhandu. 2000. The non-PP requirements of broilers in a four-phase feeding program. Poult. Sci. 79 (Suppl.1):11. (Abstr.)

Livestock Waste Facilities Handbook. 1993. Midwest Plan Service, Ames, IA.

McNabb, F. M. A., and R. A. McNabb. 1975. Proportions of ammonia, urea, urate and total nitrogen in avian urine and quantitative methods for their analysis on a single urine sample. Poult. Sci. 54:1498-1505.

Monteny, G. J. 1994. Reduction of ammonia emission from Dutch agriculture: technical solutions. Pages 429-440 in Pollution in Livestock Production Systems. I. Ap Dewi, R. F. E. Axford, I. F. M. Marai, and H. Omed, ed. CAB International, Oxon, UK.

Moran, E. T., Jr. 1979. Carcass quality changes with the broiler chickens after dietary protein restriction during the growing phase and finishing period compensatory growth. Poult. Sci. 58:1257-1270.

Morse, D. 1995. Environmental considerations of livestock producers. J. Anim Sci. 73:2733-2740.

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

Owen, J. B. 1994. Pollution in livestock production systems. Pages 1-10 in Livestock Production Systems. I. Ap Dewi, R. F. E. Axford, I. F. M. Marai, and H. Omed, ed. CAB International, Oxon, UK.

Parr, J. F., and J. D. Summers. 1991. The effects of minimizing amino acid excesses in broiler diets. Poult. Sci. 70:1540-1549.

Peisker, M. 1999. Amino acid profiles for poultry. Pages 21-31 in Recent Advances in Animal Nutrition. P. C. Garnsworthy and D. J. A. Cole, ed. Nottingham University Press, Leicestershire, UK.

Pesti, G. M., and B. R. Miller. 1997. Modeling for precision nutrition. J. Appl. Poult. Res. 6:483-494.

Pipa, F., and G. Frank. 1989. High-pressure conditioning with annular gap expander: a new way of feed processing. Adv. Feed Technol. 2:22-30.

Plavnik, I., and D. Sklan. 1995. Nutritional effects of expansion and short time extrusion on feeds for broilers. Anim. Feed Sci. Technol. 33:1-14.

Pope, T., and J. L. Emmert. 2001. Phase-feeding support maximum growth performance of broiler chicks from forty-three to seventy-one days of age. Poult. Sci. 80:345-352.

Pope, T., L. N. Loupe, J. A. Townsend, and J. L. Emmert. 2002. Growth performance of broilers using a phase-feeding approach with diets switched every other day from forty-two to sixty-three days of age. Poult. Sci. 81:466-471.

Ravindran, V., S. Cabahug, G. Ravindran, and W. L. Bryden. 1999. Influence of microbial phytase on apparent ileal amino acid digestibility of feedstuffs for broilers. Poult. Sci. 78:699-706.

Riaz, M. N. 2000. Introduction to extruders and their principles. Pages 1-21 in Extruders in Food Applications. M. N. Riaz, ed. Technomic Publishing, Lancaster, PA.

Roush, W. B. 2002. Feeding poultry. Pages 291-310 in Livestock Feeds and Feeding. R. O. Kellems and D. C. Church, ed. Prentice Hall, Upper Saddle River, NJ.

Saleh, E. A., S. E. Watkins, A. L. Waldroup, and P. W. Waldroup. 1995. Evaluating time of changing starter and grower diets on live performance and carcass characteristics of large male broilers. Poult. Sci. 74(Suppl. 1):14. (Abstr.)

SAS Institute, 1996. SAS® User's Guide: Statistics. Version 6.12 Edition. SAS Institute Inc., Cary, NC.

Shalev, B., 1995. Comparative growth and efficiency of various avian species. Pages 53-73 in World Animal Science Poultry Production. P. Hunton, ed. Elsevier, Amsterdam, Netherlands.

Sifri, M. 1997. Precision nutrition for poultry. J. Appl. Poult. Res. 6:461.

Summers, J. D., D. Spratt, and J. L. Atkinson. 1992. Broiler weight gain and carcass composition when fed diets varying in amino acid balance, dietary energy and protein level. Poult. Sci. 71:263-273.

Tasaki, I., and J. Okumura. 1964. Effect of protein level of diet on nitrogen excretion in fowls. J. Nutr. 83:34-38.

Thomas, M., D. J. van Zuilichem, and A. F. van der Poel. 1997. Physical quality of pelleted animal feed. 2. Contribution of processes and its conditions. Anim. Feed Sci. Technol. 64:173-192.

USDA-NASS Agricultural Statistics. 2002. U.S. Broiler Industry Structure. USDA-NASS, Washington, DC.

U.S. Environmental Protection Agency. 1981. Ammonia Health Effects. Office of Mobile Source and Air Pollution Content, Ann Arbor, MI.

Van Breemen, N., P. A. Burrough, E. J. Velthorst, H. F. van Dobben, T. de Wit, T. B. Ridder, and H. F. R. Reijinders. 1982. Soil acidification from atmospheric ammonium sulphate in forest canopy throughfall. Nature 299:548-550.

Verstegen, M. 1995. Strategies in the Netherlands for animal waste reduction management. The Institute of Nutrition, University of North Carolina, Chapel Hill, NC.

Verstegen, M., and S. Tamminga. 2002. Feed composition and environmental pollution. Pages 45-60 in Recent Advances in Animal Nutrition. P. C. Garnsworthy and J. Wiseman, ed. Nottingham University Press, Nottingham, UK.

Verstegen, M., S. Tamminga, and R. Greers. 1994. The effect of gaseous pollutants on animals. Pages 71-79 in Pollution Livestock Production Systems. I. Ap Dewi, R. F. E. Axford, I. F. M. Marai, and H. Omed, ed. CAB International, Oxon, UK.

Voet, D., J. G. Voet, and C. W. Pratt. 1999. Fundamentals of Biochemistry. John Wiley and Sons, Inc., New York.

Waldroup, P. W. 1999. Dietary nutrient requirements for chickens and turkey. Feedstuffs 71:66-69.

Warren, W. A., and J. L. Emmert. 2000. Efficacy of phase-feeding in supporting growth performance of broiler chicks during the starter and finisher phases. Poult. Sci. 79:764-770.

Watkins, S.E., A. L. Waldroup, and P. W. Waldroup. 1993. Effect of dietary amino acid level and time of change from starter to grower diets on performance of broilers grown to 45 days of age. Poult. Sci. 72(Suppl. 1):197. (Abstr.)

William, L. M. 2001. Development and testing of an environmental management system for organic wastes from intensive pig and poultry units. Literature review of the management of organic wastes from intensive pig and poultry units. Environmental Protection Agency. Johnstown Castle Estate, Ireland.

Yi, Z., E. T. Kornegay, and D. M. Denbow. 1996. Effect of microbial phytase on nitrogen and amino acid digestibility and nitrogen retention of turkey poults fed corn-soybean diets. Poult. Sci. 75:979-990.

Zanella, I., N. K. Sakomura, F. G. Silversides, A. Fiquerido, and M. Pack. 1999. Effect of enzyme supplementation of broiler diets based on corn and soybeans. Poult. Sci. 78:561-568.

Zhang, F., and W. B. Roush. 2002. Multiple-objective programming model for feed formulation: an example for reducing nutrient variation. Poult. Sci. 81:182-192.

APPENDIX A

EXPERIMENTAL DIETS

Diet A Experiment 1 (Chapter III)

User : 9930 — Texas A & M University
Date : 1/8/01 — Solution Report

Plant : TAMU - TAMU Research Farm
Pricing : TAMU - TAMU Research Farm
Formula : E1A - Broiler Starter

Amount	Code	Name	Per.	Cost	Low	High
458.0769	1200	Corn Yellow Grain 4-02-935	50.81	4.5400		7.7840
362.7599	2510	SBM Dehulled 48% TAMU 5-04-612	40.31	8.3800	3.3067	13.7378
1.7468	5000	DL Methionine 98%	0.20	20.0000	12.3860	1,087.1330
0.1056	5200	L-Lysine HCL 78%	0.02	14.0000		162.8830
42.7887	6000	FAT A&V Blend	4.78	15.5000	5.4943	42.7550
13.8782	7000	Limestone Ground 6-02-632	1.54	3.0000		52.8182
13.7403	7200	Mono-dicalcium PO4 16:21 6-26-137	1.53	20.0000		831.0610
3.4835	7500	Salt 6-04-152	0.39	2.5000		82,561.020
0.4500	7900	Trace Minerals TAMU 98	0.05	50.0000		50.0000
2.2500	8900	Vitamins TAMU-ROCHE 98	0.25	50.0000		50.0000
0.7200	9048	Coban 60	0.08	250.0000		250.0000
900.0000				143.5419		

	Nutrient Name	Actual	Units	Min.	Max.	Rest
1	Weight	1.0000	Lbs	1.0000	1.0000	80.6626
2	Dry Matter	90.27	Pct			
4	Crude Protein	24.00	Pct	24.00		-0.1426
9	Ether Extract	6.85	Pct		10.00	
10	Crude Fiber	2.69	Pct		5.00	
13	Calcium	0.95	Pct	0.95	0.95	-0.1849
14	Total Phosphorus	0.71	Pct			
15	Available Phos	0.45	Pct	0.45		-1.0032
16	Inorganic Phos	0.32	Pct			
18	Ca/AvPhos	2.11	Pct/Pct			
20	Poultry ME/kg	3,124	Kcal/kg	3,124	3,124	-0.0434
22	Poultry ME/lb~	1,420	Kcal/lb			
38	Xanthophyll mg/kg	8.65	mg/kg			
40	Methionine	0.55	Pct	0.55		-0.0784
41	Cystine	0.39	Pct			
42	Met + Cys~	0.94	Pct			
43	Lysine	1.34	Pct	1.34	1.34	0.8274
44	Arginine	1.62	Pct			
45	Threonine	0.90	Pct			
46	Tryptophan	0.30	Pct			
47	Glycine	0.99	Pct			
58	Dig Methionine~	0.52	Pct			
60	Dig Met + Cys~	0.84	Pct			
61	Dig Lysine~	1.21	Pct			
62	Dig Arginine~	1.49	Pct			
63	DigThreonine~	0.79	Pct			
96	Choline	1,850.35	mg/kg			
100		2.71				
104	NA+K-CL~	240.78	Meq/kg	190.00	300.00	
107	Sodium	0.17	Pct	0.17		-0.1683
108	Potassium	0.95	Pct			
109	Chloride	0.28	Pct			
112	Manganese	175.47	mg/kg			
113	Iron	276.66	mg/kg			
114	Copper	9.50	mg/kg			
115	Zinc	159.88	mg/kg			
116	Selenium	0.31	mg/kg			

Diet B Experiment 1 (Chapter III)

User : 9930
Date : 1/8/01

Texas A & M University

Solution Report

Time : 16:26

Page : 1

Plant : TAMU - TAMU Research Farm
Pricing : TAMU - TAMU Research Farm
Formula : E1B - Broiler Starter

Amount	Code	Name	Per.	Cost	Low	High
560.4404	1200	Corn Yellow Grain 4-02-935	62.25	4.5400		7.7840
270.2603	2510	SBM Dehulled 48% TAMU 5-04-612	30.00	8.3800	3.3067	13.7378
1.3602	5000	DL Methionine 98%	0.16	20.0000	12.3860	1,087.1330
0.5169	5200	L-Lysine HCL 78%	0.07	14.0000		162.8830
34.1575	6000	FAT A&V Blend	3.80	15.5000	5.4943	42.7550
13.9558	7000	Limestone Ground 6-02-632	1.55	3.0000		52.8182
12.1766	7200	Mono-dicalcium PO4 16:21 6-26-137	1.35	20.0000		831.0610
3.7122	7500	Salt 6-04-152	0.39	2.5000		82,561.020
0.4500	7900	Trace Minerals TAMU 98	0.05	50.0000		50.0000
2.2500	8900	Vitamins TAMU-ROCHE 98	0.25	50.0000		50.0000
0.7200	9048	Coban 60	0.08	250.0000		250.0000
899.9999				132.9498		

Rejected Ingredients

Code	Name	Cost	Low	Max.

	Nutrient Name	Actual	Units	Min.	Max.	Rest
1	Weight	1.0000	Lbs	1.0000	1.0000	80.6626
2	Dry Matter	90.06	Pct			
4	Crude Protein	20.00	Pct	20.00		-0.1426
9	Ether Extract	6.27	Pct		10.00	
10	Crude Fiber	2.54	Pct		5.00	
13	Calcium	0.90	Pct	0.90	0.90	-0.1849
14	Total Phosphorus	0.64	Pct			
15	Available Phos	0.40	Pct	0.40		-1.0032
16	Inorganic Phos	0.28	Pct			
18	Ca/AvPhos	2.25	Pct/Pct			
20	Poultry ME/kg	3,168	Kcal/kg	3,168	3,168	-0.0434
22	Poultry ME/lb~	1,440	Kcal/lb			
38	Xanthophyll mg/kg	10.59	mg/kg			
40	Methionine	0.46	Pct	0.46		-0.0784
41	Cystine	0.33	Pct			
42	Met + Cys~	0.79	Pct			
43	Lysine	1.10	Pct	1.10		0.8274
44	Arginine	1.30	Pct			
45	Threonine	0.74	Pct			
46	Tryptophan	0.23	Pct			
47	Glycine	0.82	Pct			
58	Dig Methionine~	0.43	Pct			
60	Dig Met + Cys~	0.71	Pct			
61	Dig Lysine~	0.99	Pct			
62	Dig Arginine~	1.19	Pct			
63	DigThreonine~	0.65	Pct			
96	Choline	1,607.48	mg/kg			
100		2.61				
104	NA+K-CL~	195.05	Meq/kg	190.00	300.00	
107	Sodium	0.18	Pct	0.18		-0.1683
108	Potassium	0.78	Pct			
109	Chloride	0.30	Pct			
112	Manganese	171.33	mg/kg			
113	Iron	248.86	mg/kg			
114	Copper	8.28	mg/kg			
115	Zinc	155.93	mg/kg			
116	Selenium	0.31	mg/kg			

Diet A Experiment 2 (Chapter III)

User : 9930
Date : 4/8/01

Texas A & M University

Solution Report

Time : 17:12

Page : 1

Plant : TAMU - TAMU Research Farm
Pricing : TAMU - TAMU Research Farm
Formula : E2A - Broiler Starter

Amount	Code	Name	Per.	Cost	Low	High
393.5037	1200	Corn Yellow Grain 4-02-935	45.21	4.5400		6.4209
411.1367	2510	SBM Dehulled 48% TAMU 5-04-612	45.13	8.3800	7.0406	13.7378
1.8124	5000	DL Methionine 98%	0.20	20.0000	12.3860	264.3495
0.0923	5200	L-Lysine HCL 78%	0.06	14.0000		17.0014
61.2873	6000	FAT A&V Blend	5.56	15.5000	7.8544	42.7550
12.4941	7000	Limestone Ground 6-02-632	1.39	3.0000		52.8182
13.4795	7200	Mono-dicalcium PO4 16:21 6-26-137	1.50	20.0000		192.5222
3.4939	7500	Salt 6-04-152	0.39	2.5000		10,004.970
0.4500	7900	Trace Minerals TAMU 98	0.05	50.0000		50.0000
2.2500	8900	Vitamins TAMU-ROCHE 98	0.25	50.0000		50.0000
899.9999				148.2252		

Rejected Ingredients

Code	Name	Cost	Low	Max.
9048	Coban 60	250.0000		

	Nutrient Name	Actual	Units	Min.	Max.	Rest
1	Weight	1.0000	Lbs	1.0000	1.0000	80.6626
2	Dry Matter	90.50	Pct			
4	Crude Protein	26.00	Pct	26.00		-0.1426
9	Ether Extract	8.59	Pct		10.00	
10	Crude Fiber	2.74	Pct		5.00	
13	Calcium	0.90	Pct	0.90	0.90	-0.1849
14	Total Phosphorus	0.72	Pct			
15	Available Phos	0.45	Pct	0.45		-1.0032
16	Inorganic Phos	0.31	Pct			
18	Ca/AvPhos	2.00	Pct/Pct			
20	Poultry ME/kg	3,200	Kcal/kg	3,200	3,200	-0.0434
22	Poultry ME/lb~	1,455	Kcal/lb			
38	Xanthophyll mg/kg	7.43	mg/kg			
40	Methionine	0.58	Pct	0.58		-0.0784
41	Cystine	0.41	Pct			
42	Met + Cys~	0.99	Pct			
43	Lysine	1.45	Pct	1.45		0.8274
44	Arginine	1.79	Pct			
45	Threonine	0.98	Pct			
46	Tryptophan	0.33	Pct			
47	Glycine	1.08	Pct			
58	Dig Methionine~	0.55	Pct			
60	Dig Met + Cys~	0.89	Pct			
61	Dig Lysine~	1.34	Pct			
62	Dig Arginine~	1.64	Pct			
63	DigThreonine~	0.86	Pct			
96	Choline	1,971.98	mg/kg			
100		3.05				
104	NA+K-CL~	262.46	Meq/kg	190.00	300.00	
107	Sodium	0.17	Pct	0.17		-0.1683
108	Potassium	1.04	Pct			
109	Chloride	0.28	Pct			
112	Manganese	177.20	mg/kg			
113	Iron	276.89	mg/kg			
114	Copper	10.09	mg/kg			
115	Zinc	161.49	mg/kg			
116	Selenium	0.32	mg/kg			

Diet B Experiment 2 (Chapter III)

User : 9930
Date : 4/4/01

Texas A & M University

Solution Report

Time : 17:34

Page : 1

Plant : TAMU - TAMU Research Farm
Pricing : TAMU - TAMU Research Farm
Formula : E2B - Broiler Starter

Amount	Code	Name	Per.	Cost	Low	High
557.0745	1200	Corn Yellow Grain 4-02-935	63.22	4.5400		6.4209
269.4505	2510	SBM Dehulled 48% TAMU 5-04-612	29.25	8.3800	7.0406	15.7487
1.3719	5000	DL Methionine 98%	0.15	20.0000	11.9320	264.3495
1.2288	5200	L-Lysine HCL 78%	0.09	14.0000		17.0014
38.5396	6000	FAT A&V Blend	3.64	15.5000	7.8544	51.7980
13.9544	7000	Limestone Ground 6-02-632	1.55	3.0000		52.7581
12.1979	7200	Mono-dicalcium PO4 16:21 6-26-137	1.36	20.0000		192.5222
3.4824	7500	Salt 6-04-152	0.39	2.5000		10,004.970
0.4500	7900	Trace Minerals TAMU 98	0.05	50.0000		50.0000
2.2500	8900	Vitamins TAMU-ROCHE 98	0.25	50.0000		50.0000
899.9999				130.1921		

Rejected Ingredients

Code	Name	Cost	Low	Max.
9048	Coban 60	250.0000		

	Nutrient Name	Actual	Units	Min.	Max.	Rest
1	Weight	1.0000	Lbs	1.0000	1.0000	79.9870
2	Dry Matter	90.10	Pct			
4	Crude Protein	20.00	Pct	20.00		-0.1347
9	Ether Extract	6.72	Pct		10.00	
10	Crude Fiber	2.53	Pct		5.00	
13	Calcium	0.90	Pct	0.90	0.90	-0.1835
14	Total Phosphorus	0.64	Pct			
15	Available Phos	0.40	Pct	0.40		-1.0018
16	Inorganic Phos	0.28	Pct			
18	Ca/AvPhos	2.25	Pct/Pct			
20	Poultry ME/kg	3,200	Kcal/kg	3,200	3,200	-0.0433
22	Poultry ME/lb~	1,455	Kcal/lb			
38	Xanthophyll mg/kg	10.52	mg/kg			
40	Methionine	0.46	Pct	0.46		-0.0829
41	Cystine	0.33	Pct			
42	Met + Cys~	0.79	Pct			
43	Lysine	1.10	Pct	1.10		
44	Arginine	1.30	Pct			
45	Threonine	0.74	Pct			
46	Tryptophan	0.23	Pct			
47	Glycine	0.82	Pct			
58	Dig Methionine~	0.43	Pct			
60	Dig Met + Cys~	0.71	Pct			
61	Dig Lysine~	1.05	Pct			
62	Dig Arginine~	1.19	Pct			
63	DigThreonine~	0.64	Pct			
96	Choline	1,603.27	mg/kg			
100		2.69				
104	NA+K-CL~	190.00	Meq/kg	190.00	300.00	-0.0093
107	Sodium	0.17	Pct	0.17		-0.1676
108	Potassium	0.78	Pct			
109	Chloride	0.30	Pct			
112	Manganese	171.27	mg/kg			
113	Iron	248.73	mg/kg			
114	Copper	8.25	mg/kg			
115	Zinc	155.82	mg/kg			
116	Selenium	0.31	mg/kg			

Broiler Starter Diet Industry Four-Phase (Chapter IV)

User : 9930 Texas A & M University
Date : 1/8/02
Solution Report
Time : 17:47

Page : 1

Plant : TAMU - TAMU Research Farm
Pricing : TAMU - TAMU Research Farm
Formula : AGRS - Broiler Starter Stored : 7/24/03 Ver : 1 Cost : 136.8391

Amount	Code	Name	Per.	Cost	Low	High
504.0540	1200	Corn Yellow Grain 4-02-935	56.01	4.5400		7.9409
332.8907	2500	SBM Dehulled 48% 5-04-612	36.99	8.3800	3.0772	76,213.640
1.8757	5000	DL Methionine 98%	0.21	20.0000	4.4599	549.6629
27.6626	6000	FAT A&V Blend	3.07	15.5000	5.5486	393.8688
12.9481	7000	Limestone Ground 6-02-632	1.44	3.0000		51.7728
13.0209	7200	Mono-dicalcium PO4 16:21 6-26-137	1.45	20.0000		882.2959
4.1730	7500	Salt 6-04-152	0.46	2.5000		13,833.840
0.4500	7900	Trace Minerals TAMU 98	0.05	50.0000		50.0000
2.2500	8900	Vitamins TAMU-ROCHE 98	0.25	50.0000		50.0000
0.6750	9048	Coban 60	0.08	250.0000		3,000,000,
900.0000				136.8391		

Rejected Ingredients

Code	Name	Cost	Low	Max.
5200	L-Lysine HCL 78%	14.0000	4.2783	

	Nutrient Name	Actual	Units	Min.	Max.	Rest
1	Weight	1.0000	Lbs	1.0000	1.0000	64.7495
2	Dry Matter	90.06	Pct			
4	Crude Protein	22.82	Pct	21.22		
9	Ether Extract	5.42	Pct		10.00	
10	Crude Fiber	2.67	Pct		5.00	
13	Calcium	0.89	Pct	0.89	1.00	-0.1639
14	Total Phosphorus	0.69	Pct			
15	Available Phos	0.43	Pct	0.43		-0.9813
16	Inorganic Phos	0.30	Pct			
18	Ca/AvPhos	2.07	Pct/Pct			
20	Poultry ME/kg	3,063	Kcal/kg	3,063		-0.0416
22	Poultry ME/lb~	1,392	Kcal/lb			
38	Xanthophyll mg/kg	9.52	mg/kg			
40	Methionine	0.55	Pct			
41	Cystine	0.37	Pct			
42	Met + Cys~	0.92	Pct	0.92		-3.1788
43	Lysine	1.24	Pct	1.23		
44	Arginine	1.50	Pct	1.50		-1.7395
45	Threonine	0.85	Pct	0.84		
46	Tryptophan	0.31	Pct	0.24		
47	Glycine	0.94	Pct			
58	Dig Methionine~	0.52	Pct			
60	Dig Met + Cys~	0.83	Pct			
61	Dig Lysine~	1.11	Pct			
62	Dig Arginine~	1.37	Pct			
63	DigThreonine~	0.75	Pct			
96	Choline	1,778.25	mg/kg			
100		2.43				
104	NA+K-CL~	228.47	Meq/kg	200.00	300.00	
107	Sodium	0.20	Pct	0.20	0.20	-0.1478
108	Potassium	0.90	Pct			
109	Chloride	0.32	Pct			
112	Manganese	174.17	mg/kg			
113	Iron	264.10	mg/kg			
114	Copper	9.15	mg/kg			
115	Zinc	158.82	mg/kg			
116	Selenium	0.31	mg/kg			

Broiler Grower Diet Industry Four-Phase (Chapter IV)

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Plant : TAMU - TAMU Research Farm
Pricing : TAMU - TAMU Research Farm
Formula : AGRG - Broiler Grower Stored : 7/24/03 Ver : 1 Cost : 133.3054

Amount	Code	Name	Per.	Cost	Low	High
670.9174	1200	Corn Yellow Grain 4-02-935	60.99	4.5400		7.9409
350.3022	2500	SBM Dehulled 48% 5-04-612	31.85	8.3800	3.0772	76,213.640
2.3321	5000	DL Methionine 98%	0.21	20.0000	4.4599	549.6629
38.1231	6000	FAT A&V Blend	3.47	15.5000	5.5486	393.8688
14.8929	7000	Limestone Ground 6-02-632	1.35	3.0000		51.7728
14.2029	7200	Mono-dicalcium PO4 16:21 6-26-137	1.29	20.0000		882.2959
5.1046	7500	Salt 6-04-152	0.46	2.5000		13,833.840
0.5500	7900	Trace Minerals TAMU 98	0.05	50.0000		50.0000
2.7500	8900	Vitamins TAMU-ROCHE 98	0.25	50.0000		50.0000
0.8250	9048	Coban 60	0.08	250.0000		3,000,000,
1,100.0000				133.3053		

Rejected Ingredients

Code	Name	Cost	Low	Max.
5200	L-Lysine HCL 78%	14.0000	4.2783	

	Nutrient Name	Actual	Units	Min.	Max.	Rest
1	Weight	1.0000	Lbs	1.0000	1.0000	64.7495
2	Dry Matter	90.02	Pct			
4	Crude Protein	20.75	Pct	19.40		
9	Ether Extract	5.93	Pct		10.00	
10	Crude Fiber	2.58	Pct		5.00	
13	Calcium	0.82	Pct	0.82	1.00	-0.1639
14	Total Phosphorus	0.64	Pct			
15	Available Phos	0.39	Pct	0.39		-0.9813
16	Inorganic Phos	0.27	Pct			
18	Ca/AvPhos	2.10	Pct/Pct			
20	Poultry ME/kg	3,140	Kcal/kg	3,140		-0.0416
22	Poultry ME/lb~	1,427	Kcal/lb			
38	Xanthophyll mg/kg	10.37	mg/kg			
40	Methionine	0.53	Pct			
41	Cystine	0.34	Pct			
42	Met + Cys~	0.87	Pct	0.87		-3.1788
43	Lysine	1.10	Pct	1.10		
44	Arginine	1.34	Pct	1.34		-1.7395
45	Threonine	0.77	Pct	0.76		
46	Tryptophan	0.27	Pct	0.22		
47	Glycine	0.85	Pct			
58	Dig Methionine~	0.50	Pct			
60	Dig Met + Cys~	0.79	Pct			
61	Dig Lysine~	0.99	Pct			
62	Dig Arginine~	1.23	Pct			
63	DigThreonine~	0.67	Pct			
96	Choline	1,653.63	mg/kg			
100		2.54				
104	NA+K-CL~	206.26	Meq/kg	200.00	300.00	
107	Sodium	0.20	Pct	0.20	0.20	-0.1478
108	Potassium	0.82	Pct			
109	Chloride	0.32	Pct			
112	Manganese	171.84	mg/kg			
113	Iron	241.90	mg/kg			
114	Copper	8.50	mg/kg			
115	Zinc	156.58	mg/kg			
116	Selenium	0.31	mg/kg			

Broiler Withdrawal 1 Diet Industry Four-Phase (Chapter IV)

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Texas A & M University
Solution Report

Plant : TAMU - TAMU Research Farm
Pricing : TAMU - TAMU Research Farm
Formula : AGRW - Broiler withdrawal 1 Stored : 7/24/03 Ver : 1 Cost : 131.8237

Amount	Code	Name	Per.	Cost	Low	High
471.1194	1200	Corn Yellow Grain 4-02-935	62.82	4.5400		7.9347
227.6197	2500	SBM Dehulled 48% 5-04-612	30.35	8.3800	3.0772	3,051,784.
0.7807	5000	DL Methionine 98%	0.10	20.0000	4.1845	549.6629
27.6095	6000	FAT A&V Blend	3.68	15.5000	5.5960	535.3922
9.2218	7000	Limestone Ground 6-02-632	1.23	3.0000		51.7699
8.3207	7200	Mono-dicalcium PO4 16:21 6-26-137	1.11	20.0000		882.2959
2.5159	7500	Salt 6-04-152	0.34	2.5000		13,721.040
0.3750	7900	Trace Minerals TAMU 98	0.05	50.0000		50.0000
1.8750	8900	Vitamins TAMU-ROCHE 98	0.25	50.0000		50.0000
0.5625	9048	Coban 60	0.08	250.0000		3,000,000,
750.0000				131.8237		

Rejected Ingredients

Code	Name	Cost	Low	Max.
5200	L-Lysine HCL 78%	14.0000		

	Nutrient Name	Actual	Units	Min.	Max.	Rest
1	Weight	1.0000	Lbs	1.0000	1.0000	73.8185
2	Dry Matter	89.98	Pct			
4	Crude Protein	20.12	Pct	17.10		
9	Ether Extract	6.19	Pct		10.00	
10	Crude Fiber	2.57	Pct		5.00	
13	Calcium	0.74	Pct	0.74	1.00	-0.1628
14	Total Phosphorus	0.60	Pct			
15	Available Phos	0.35	Pct	0.35		-0.9812
16	Inorganic Phos	0.23	Pct			
18	Ca/AvPhos	2.11	Pct/Pct			
20	Poultry ME/kg	3,180	Kcal/kg	3,180		-0.0426
22	Poultry ME/lb~	1,445	Kcal/lb			
38	Xanthophyll mg/kg	10.68	mg/kg			
40	Methionine	0.42	Pct			
41	Cystine	0.33	Pct			
42	Met + Cys~	0.75	Pct	0.75		-3.2335
43	Lysine	1.06	Pct	0.94		
44	Arginine	1.29	Pct	1.15		
45	Threonine	0.75	Pct	0.68		
46	Tryptophan	0.26	Pct	0.18		
47	Glycine	0.83	Pct			
58	Dig Methionine~	0.39	Pct			
60	Dig Met + Cys~	0.67	Pct			
61	Dig Lysine~	0.95	Pct			
62	Dig Arginine~	1.18	Pct			
63	DigThreonine~	0.65	Pct			
96	Choline	1,619.01	mg/kg			
100		2.60				
104	NA+K-CL~	200.00	Meq/kg	200.00	300.00	-0.2540
107	Sodium	0.15	Pct	0.15	0.15	-0.1639
108	Potassium	0.79	Pct			
109	Chloride	0.24	Pct			
112	Manganese	170.78	mg/kg			
113	Iron	221.27	mg/kg			
114	Copper	8.30	mg/kg			
115	Zinc	155.72	mg/kg			
116	Selenium	0.31	mg/kg			

Broiler Withdrawal 2 Diet Industry Four-Phase (Chapter IV)

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Texas A & M University

Solution Report

Plant : TAMU - TAMU Research Farm
Pricing : TAMU - TAMU Research Farm
Formula : AGRW2 - Broiler withdrawal 2 Stored : 7/24/03 Ver : 1 Cost : 128.1018

Amount	Code	Name	Per.	Cost	Low	High
534.9968	1200	Corn Yellow Grain 4-02-935	62.94	4.5400		7.9347
257.9307	2500	SBM Dehulled 48% 5-04-612	30.34	8.3800	3.0772	3,051,784.
0.6212	5000	DL Methionine 98%	0.07	20.0000	4.1845	549.6629
33.6582	6000	FAT A&V Blend	3.96	15.5000	5.5960	535.3922
10.2396	7000	Limestone Ground 6-02-632	1.20	3.0000		51.7699
7.8074	7200	Mono-dicalcium PO4 16:21 6-26-137	0.92	20.0000		882.2959
2.1961	7500	Salt 6-04-152	0.26	2.5000		13,721.040
0.4250	7900	Trace Minerals TAMU 98	0.05	50.0000		50.0000
2.1250	8900	Vitamins TAMU-ROCHE 98	0.25	50.0000		50.0000
850.0000				128.1018		

Rejected Ingredients

Code	Name	Cost	Low	Max.
5200	L-Lysine HCL 78%	14.0000		
9048	Coban 60	250.0000		

	Nutrient Name	Actual	Units	Min.	Max.	Rest
1	Weight	1.0000	Lbs	1.0000	1.0000	73.8185
2	Dry Matter	89.97	Pct			
4	Crude Protein	20.11	Pct	16.41		
9	Ether Extract	6.46	Pct		10.00	
10	Crude Fiber	2.57	Pct		5.00	
13	Calcium	0.70	Pct	0.70	1.00	-0.1628
14	Total Phosphorus	0.56	Pct			
15	Available Phos	0.31	Pct	0.31		-0.9812
16	Inorganic Phos	0.19	Pct			
18	Ca/AvPhos	2.26	Pct/Pct			
20	Poultry ME/kg	3,208	Kcal/kg	3,208		-0.0426
22	Poultry ME/lb~	1,458	Kcal/lb			
38	Xanthophyll mg/kg	10.70	mg/kg			
40	Methionine	0.39	Pct			
41	Cystine	0.33	Pct			
42	Met + Cys~	0.72	Pct	0.72		-3.2335
43	Lysine	1.06	Pct	0.89		
44	Arginine	1.30	Pct	1.09		
45	Threonine	0.75	Pct	0.64		
46	Tryptophan	0.26	Pct	0.18		
47	Glycine	0.83	Pct			
58	Dig Methionine~	0.36	Pct			
60	Dig Met + Cys~	0.64	Pct			
61	Dig Lysine~	0.95	Pct			
62	Dig Arginine~	1.18	Pct			
63	DigThreonine~	0.65	Pct			
96	Choline	1,619.43	mg/kg			
100		2.66				
104	NA+K-CL~	200.00	Meq/kg	200.00	300.00	-0.2540
107	Sodium	0.12	Pct	0.12	0.12	-0.1639
108	Potassium	0.79	Pct			
109	Chloride	0.20	Pct			
112	Manganese	170.21	mg/kg			
113	Iron	203.60	mg/kg			
114	Copper	8.28	mg/kg			
115	Zinc	155.36	mg/kg			
116	Selenium	0.30	mg/kg			

Diet A Industry Multi-phase (Chapter IV)

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Plant : TAMU - TAMU Research Farm
Pricing : TAMU - TAMU Research Farm
Formula : AGRSMP - Broiler Starter Stored : 7/24/03 Ver : 1 Cost : 139.4502

Amount	Code	Name	Per.	Cost	Low	High
212.3428	1200	Corn Yellow Grain 4-02-935	53.09	4.5400		7.9409
158.4223	2500	SBM Dehulled 48% 5-04-612	39.61	8.3800	3.0772	76,213.640
0.8505	5000	DL Methionine 98%	0.21	20.0000	4.4599	549.6629
12.9524	6000	FAT A&V Blend	3.24	15.5000	5.5486	393.8688
5.9746	7000	Limestone Ground 6-02-632	1.49	3.0000		51.7728
6.1028	7200	Mono-dicalcium PO4 16:21 6-26-137	1.53	20.0000		882.2959
1.8546	7500	Salt 6-04-152	0.46	2.5000		13,833.840
0.2000	7900	Trace Minerals TAMU 98	0.05	50.0000		50.0000
1.0000	8900	Vitamins TAMU-ROCHE 98	0.25	50.0000		50.0000
0.3000	9048	Coban 60	0.08	250.0000		3,000,000,
400.0000				139.4502		

Rejected Ingredients

Code	Name	Cost	Low	Max.
5200	L-Lysine HCL 78%	14.0000	4.2783	

	Nutrient Name	Actual	Units	Min.	Max.	Rest
1	Weight	1.0000	Lbs	1.0000	1.0000	64.7495
2	Dry Matter	90.11	Pct			
4	Crude Protein	23.85	Pct	22.18		
9	Ether Extract	5.49	Pct		10.00	
10	Crude Fiber	2.71	Pct		5.00	
13	Calcium	0.93	Pct	0.93	1.00	-0.1639
14	Total Phosphorus	0.71	Pct			
15	Available Phos	0.45	Pct	0.45		-0.9813
16	Inorganic Phos	0.32	Pct			
18	Ca/AvPhos	2.07	Pct/Pct			
20	Poultry ME/kg	3,044	Kcal/kg	3,044		-0.0416
22	Poultry ME/lb~	1,384	Kcal/lb			
38	Xanthophyll mg/kg	9.02	mg/kg			
40	Methionine	0.57	Pct			
41	Cystine	0.38	Pct			
42	Met + Cys~	0.95	Pct	0.95		-3.1788
43	Lysine	1.31	Pct	1.30		
44	Arginine	1.58	Pct	1.58		-1.7395
45	Threonine	0.89	Pct	0.88		
46	Tryptophan	0.32	Pct	0.25		
47	Glycine	0.99	Pct			
58	Dig Methionine~	0.54	Pct			
60	Dig Met + Cys~	0.85	Pct			
61	Dig Lysine~	1.18	Pct			
62	Dig Arginine~	1.45	Pct			
63	DigThreonine~	0.78	Pct			
96	Choline	1,840.00	mg/kg			
100		2.45				
104	NA+K-CL~	239.50	Meq/kg	200.00	300.00	
107	Sodium	0.20	Pct	0.20	0.20	-0.1478
108	Potassium	0.95	Pct			
109	Chloride	0.32	Pct			
112	Manganese	175.32	mg/kg			
113	Iron	275.44	mg/kg			
114	Copper	9.46	mg/kg			
115	Zinc	159.89	mg/kg			
116	Selenium	0.31	mg/kg			

Diet B Industry Multi-phase (Chapter IV)

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Plant : TAMU - TAMU Research Farm
Pricing : TAMU - TAMU Research Farm
Formula : AGRGMP - Broiler grower

Amount	Code	Name	Per.	Cost	Low	High
90.2536	1200	Corn Yellow Grain 4-02-935	60.17	4.5400		7.9409
50.0585	2500	SBM Dehulled 48% 5-04-612	33.37	8.3800	3.0772	76,213.640
0.3054	5000	DL Methionine 98%	0.20	20.0000	4.4599	549.6629
4.1760	6000	FAT A&V Blend	2.78	15.5000	5.5486	393.8688
2.0722	7000	Limestone Ground 6-02-632	1.38	3.0000		51.7728
1.9889	7200	Mono-dicalcium PO4 16:21 6-26-137	1.33	20.0000		882.2959
0.6954	7500	Salt 6-04-152	0.46	2.5000		13,833.840
0.0750	7900	Trace Minerals TAMU 98	0.05	50.0000		50.0000
0.3750	8900	Vitamins TAMU-ROCHE 98	0.25	50.0000		50.0000
150.0000				129.3747		

Rejected Ingredients

Code	Name	Cost	Low	Max.
5200	L-Lysine HCL 78%	14.0000	4.2783	
9048	Coban 60	250.0000		

	Nutrient Name	Actual	Units	Min.	Max.	Rest
1	Weight	1.0000	Lbs	1.0000	1.0000	64.7495
2	Dry Matter	89.97	Pct			
4	Crude Protein	21.42	Pct	19.94		
9	Ether Extract	5.26	Pct		10.00	
10	Crude Fiber	2.63	Pct		5.00	
13	Calcium	0.84	Pct	0.84	1.00	-0.1639
14	Total Phosphorus	0.65	Pct			
15	Available Phos	0.40	Pct	0.40		-0.9813
16	Inorganic Phos	0.28	Pct			
18	Ca/AvPhos	2.10	Pct/Pct			
20	Poultry ME/kg	3,088	Kcal/kg	3,088		-0.0416
22	Poultry ME/lb~	1,404	Kcal/lb			
38	Xanthophyll mg/kg	10.23	mg/kg			
40	Methionine	0.53	Pct			
41	Cystine	0.35	Pct			
42	Met + Cys~	0.88	Pct	0.88		-3.1788
43	Lysine	1.14	Pct	1.14		
44	Arginine	1.39	Pct	1.39		-1.7395
45	Threonine	0.80	Pct	0.78		
46	Tryptophan	0.28	Pct	0.23		
47	Glycine	0.88	Pct			
58	Dig Methionine~	0.50	Pct			
60	Dig Met + Cys~	0.79	Pct			
61	Dig Lysine~	1.03	Pct			
62	Dig Arginine~	1.27	Pct			
63	DigThreonine~	0.70	Pct			
96	Choline	1,693.52	mg/kg			
100		2.41				
104	NA+K-CL~	213.34	Meq/kg	200.00	300.00	
107	Sodium	0.20	Pct	0.20	0.20	-0.1478
108	Potassium	0.84	Pct			
109	Chloride	0.32	Pct			
112	Manganese	172.54	mg/kg			
113	Iron	247.80	mg/kg			
114	Copper	8.71	mg/kg			
115	Zinc	157.34	mg/kg			
116	Selenium	0.31	mg/kg			

Diet C Industry Multi-phase (Chapter IV)

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Plant : TAMU - TAMU Research Farm
Pricing : TAMU - TAMU Research Farm
Formula : AGRWMP - Broiler withdrawal

Amount	Code	Name	Per.	Cost	Low	High
375.6899	1200	Corn Yellow Grain 4-02-935	62.61	4.5400		7.9347
182.4392	2500	SBM Dehulled 48% 5-04-612	30.41	8.3800	3.0772	3,051,784.
0.3792	5000	DL Methionine 98%	0.06	20.0000	4.1845	549.6629
24.8102	6000	FAT A&V Blend	4.14	15.5000	5.5960	535.3922
7.1496	7000	Limestone Ground 6-02-632	1.19	3.0000		51.7699
4.9432	7200	Mono-dicalcium PO4 16:21 6-26-137	0.82	20.0000		882.2959
2.7886	7500	Salt 6-04-152	0.46	2.5000		13,721.040
0.3000	7900	Trace Minerals TAMU 98	0.05	50.0000		50.0000
1.5000	8900	Vitamins TAMU-ROCHE 98	0.25	50.0000		50.0000
600.0000				128.1300		

Rejected Ingredients

Code	Name	Cost	Low	Max.
5200	L-Lysine HCL 78%	14.0000		
9048	Coban 60	250.0000		

	Nutrient Name	Actual	Units	Min.	Max.	Rest
1	Weight	1.0000	Lbs	1.0000	1.0000	73.8185
2	Dry Matter	89.99	Pct			
4	Crude Protein	20.11	Pct	16.11		
9	Ether Extract	6.61	Pct		10.00	
10	Crude Fiber	2.56	Pct		5.00	
13	Calcium	0.68	Pct	0.68	1.00	-0.1628
14	Total Phosphorus	0.54	Pct			
15	Available Phos	0.29	Pct	0.29		-0.9812
16	Inorganic Phos	0.17	Pct			
18	Ca/AvPhos	2.34	Pct/Pct			
20	Poultry ME/kg	3,214	Kcal/kg	3,214		-0.0426
22	Poultry ME/lb~	1,461	Kcal/lb			
38	Xanthophyll mg/kg	10.64	mg/kg			
40	Methionine	0.38	Pct			
41	Cystine	0.33	Pct			
42	Met + Cys~	0.71	Pct	0.71		-3.2335
43	Lysine	1.06	Pct	0.87		
44	Arginine	1.30	Pct	1.06		
45	Threonine	0.75	Pct	0.62		
46	Tryptophan	0.26	Pct	0.18		
47	Glycine	0.83	Pct			
58	Dig Methionine~	0.35	Pct			
60	Dig Met + Cys~	0.63	Pct			
61	Dig Lysine~	0.95	Pct			
62	Dig Arginine~	1.19	Pct			
63	DigThreonine~	0.65	Pct			
96	Choline	1,619.76	mg/kg			
100		2.69				
104	NA+K-CL~	200.00	Meq/kg	200.00	300.00	-0.2540
107	Sodium	0.20	Pct	0.20	0.20	-0.1639
108	Potassium	0.79	Pct			
109	Chloride	0.32	Pct			
112	Manganese	169.93	mg/kg			
113	Iron	194.88	mg/kg			
114	Copper	8.26	mg/kg			
115	Zinc	155.14	mg/kg			
116	Selenium	0.30	mg/kg			

Diet C EFG Model Multi-phase (Chapter IV)

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Texas A & M University

Solution Report

Plant : TAMU - TAMU Research Farm
Pricing : TAMU - TAMU Research Farm
Formula : EFGS - Broiler Starter

Amount	Code	Name	Per.	Cost	Low	High
188.6869	1200	Corn Yellow Grain 4-02-935	47.17	4.5400		8.0012
173.9470	2500	SBM Dehulled 48% 5-04-612	43.49	8.3800	3.3854	38,756.020
0.0233	5000	DL Methionine 98%	0.01	20.0000	4.1599	512.9720
1.1683	5200	L-Lysine HCL 78%	0.29	14.0000	3.9539	161.2286
20.6628	6000	FAT A&V Blend	5.17	15.5000	5.0301	564.6016
5.9323	7000	Limestone Ground 6-02-632	1.48	3.0000		52.4202
6.2208	7200	Mono-dicalcium PO4 16:21 6-26-137	1.56	20.0000		816.0773
1.8587	7500	Salt 6-04-152	0.46	2.5000		15,126.000
0.2000	7900	Trace Minerals TAMU 98	0.05	50.0000		50.0000
1.0000	8900	Vitamins TAMU-ROCHE 98	0.25	50.0000		50.0000
0.3000	9048	Coban 60	0.08	250.0000		3,000,000,
400.0000				146.6634		

Rejected Ingredients

Code	Name	Cost	Low	Max.

	Nutrient Name	Actual	Units	Min.	Max.	Rest
1	Weight	1.0000	Lbs	1.0000	1.0000	74.5970
2	Dry Matter	90.35	Pct			
4	Crude Protein	25.38	Pct			
9	Ether Extract	7.13	Pct		10.00	
10	Crude Fiber	2.73	Pct		5.00	
13	Calcium	0.94	Pct	0.94	1.00	-0.1769
14	Total Phosphorus	0.73	Pct			
15	Available Phos	0.46	Pct	0.46		-0.9948
16	Inorganic Phos	0.33	Pct			
18	Ca/AvPhos	2.04	Pct/Pct			
20	Poultry ME/kg	3,117	Kcal/kg	3,117		-0.0427
22	Poultry ME/lb~	1,417	Kcal/lb			
38	Xanthophyll mg/kg	8.02	mg/kg			
40	Methionine	0.38	Pct			
41	Cystine	0.40	Pct			
42	Met + Cys~	0.78	Pct	0.78		-3.2382
43	Lysine	1.64	Pct	1.64		-2.5423
44	Arginine	1.69	Pct	1.56		
45	Threonine	0.95	Pct	0.95		-3.2221
46	Tryptophan	0.35	Pct	0.24		
47	Glycine	1.05	Pct			
58	Dig Methionine~	0.35	Pct			
60	Dig Met + Cys~	0.68	Pct			
61	Dig Lysine~	1.50	Pct			
62	Dig Arginine~	1.55	Pct			
63	DigThreonine~	0.83	Pct			
96	Choline	1,924.59	mg/kg			
100		2.76				
104	NA+K-CL~	238.64	Meq/kg	200.00	300.00	
107	Sodium	0.20	Pct	0.20	0.20	-0.1605
108	Potassium	1.00	Pct			
109	Chloride	0.38	Pct			
112	Manganese	176.67	mg/kg			
113	Iron	281.82	mg/kg			
114	Copper	9.87	mg/kg			
115	Zinc	161.02	mg/kg			
116	Selenium	0.32	mg/kg			

Diet B EFG Model Multi-phase (Chapter IV)

User : 9930 | Texas A & M University
Date : 1/8/02
Solution Report
Time : 18:19

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Plant : TAMU - TAMU Research Farm
Pricing : TAMU - TAMU Research Farm
Formula : EFGG1 - Broiler grower Coban

Amount	Code	Name	Per.	Cost	Low	High
90.5134	1200	Corn Yellow Grain 4-02-935	60.34	4.5400		7.9232
47.7255	2500	SBM Dehulled 48% 5-04-612	31.82	8.3800	3.3854	214,627.50
0.0773	5000	DL Methionine 98%	0.05	20.0000	4.3296	512.9720
0.1548	5200	L-Lysine HCL 78%	0.10	14.0000		161.2286
6.2596	6000	FAT A&V Blend	4.17	15.5000	5.6753	476.2067
2.0694	7000	Limestone Ground 6-02-632	1.38	3.0000		51.6639
1.9409	7200	Mono-dicalcium PO4 16:21 6-26-137	1.29	20.0000		816.0773
0.6966	7500	Salt 6-04-152	0.46	2.5000		13,534.730
0.0750	7900	Trace Minerals TAMU 98	0.05	50.0000		50.0000
0.3750	8900	Vitamins TAMU-ROCHE 98	0.25	50.0000		50.0000
0.1125	9048	Coban 60	0.08	250.0000		3,000,000,
150.0000				134.5335		

Rejected Ingredients

Code	Name	Cost	Low	Max.

	Nutrient Name	Actual	Units	Min.	Max.	Rest
1	Weight	1.0000	Lbs	1.0000	1.0000	69.0226
2	Dry Matter	90.09	Pct			
4	Crude Protein	20.69	Pct			
9	Ether Extract	6.58	Pct		10.00	
10	Crude Fiber	2.57	Pct		5.00	
13	Calcium	0.83	Pct	0.83	1.00	-0.1611
14	Total Phosphorus	0.64	Pct			
15	Available Phos	0.39	Pct	0.39		-0.9790
16	Inorganic Phos	0.27	Pct			
18	Ca/AvPhos	2.13	Pct/Pct			
20	Poultry ME/kg	3,179	Kcal/kg	3,179		-0.0421
22	Poultry ME/lb~	1,445	Kcal/lb			
38	Xanthophyll mg/kg	10.26	mg/kg			
40	Methionine	0.37	Pct			
41	Cystine	0.34	Pct			
42	Met + Cys~	0.71	Pct	0.71		-3.2045
43	Lysine	1.18	Pct	1.18		-13.9489
44	Arginine	1.34	Pct	1.21		
45	Threonine	0.77	Pct	0.75		
46	Tryptophan	0.27	Pct	0.18		
47	Glycine	0.85	Pct			
58	Dig Methionine~	0.35	Pct			
60	Dig Met + Cys~	0.63	Pct			
61	Dig Lysine~	1.07	Pct			
62	Dig Arginine~	1.22	Pct			
63	DigThreonine~	0.67	Pct			
96	Choline	1,649.96	mg/kg			
100		2.67				
104	NA+K-CL~	200.00	Meq/kg	200.00	300.00	-0.1650
107	Sodium	0.20	Pct	0.20	0.20	-0.1562
108	Potassium	0.81	Pct			
109	Chloride	0.34	Pct			
112	Manganese	171.79	mg/kg			
113	Iron	242.32	mg/kg			
114	Copper	8.48	mg/kg			
115	Zinc	156.45	mg/kg			
116	Selenium	0.31	mg/kg			

Diet C EFG Model Multi-phase (Chapter IV)

User : 9930 Texas A & M University
Date : 1/8/03
Solution Report
Time : 18:20

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Plant : TAMU - TAMU Research Farm
Pricing : TAMU - TAMU Research Farm
Formula : EFGW - Broiler withdrawl

Amount	Code	Name	Per.	Cost	Low	High
367.3794	1200	Corn Yellow Grain 4-02-935	61.23	4.5400		7.9086
183.3671	2500	SBM Dehulled 48% 5-04-612	30.56	8.3800	2.9281	3,056,193.
28.5404	6000	FAT A&V Blend	4.76	15.5000	5.6984	535.3922
8.3036	7000	Limestone Ground 6-02-632	1.38	3.0000		51.6859
7.8223	7200	Mono-dicalcium PO4 16:21 6-26-137	1.30	20.0000		911.7817
2.7872	7500	Salt 6-04-152	0.46	2.5000		13,522.390
0.3000	7900	Trace Minerals TAMU 98	0.05	50.0000		50.0000
1.5000	8900	Vitamins TAMU-ROCHE 98	0.25	50.0000		50.0000
600.0000				130.8407		

Rejected Ingredients

Code	Name	Cost	Low	Max.
5000	DL Methionine 98%	20.0000	4.1845	
5200	L-Lysine HCL 78%	14.0000		
9048	Coban 60	250.0000		

	Nutrient Name	Actual	Units	Min.	Max.	Rest
1	Weight	1.0000	Lbs	1.0000	1.0000	72.8566
2	Dry Matter	90.12	Pct			
4	Crude Protein	20.03	Pct			
9	Ether Extract	7.15	Pct		10.00	
10	Crude Fiber	2.54	Pct		5.00	
13	Calcium	0.83	Pct	0.83	1.00	-0.1612
14	Total Phosphorus	0.63	Pct			
15	Available Phos	0.39	Pct	0.39		-0.9795
16	Inorganic Phos	0.27	Pct			
18	Ca/AvPhos	2.13	Pct/Pct			
20	Poultry ME/kg	3,225	Kcal/kg	3,225		-0.0425
22	Poultry ME/lb~	1,466	Kcal/lb			
38	Xanthophyll mg/kg	10.41	mg/kg			
40	Methionine	0.31	Pct			
41	Cystine	0.33	Pct			
42	Met + Cys~	0.65	Pct	0.55		
43	Lysine	1.06	Pct	0.87		
44	Arginine	1.30	Pct	0.91		
45	Threonine	0.75	Pct	0.57		
46	Tryptophan	0.26	Pct	0.14		
47	Glycine	0.83	Pct			
58	Dig Methionine~	0.29	Pct			
60	Dig Met + Cys~	0.56	Pct			
61	Dig Lysine~	0.95	Pct			
62	Dig Arginine~	1.19	Pct			
63	DigThreonine~	0.65	Pct			
96	Choline	1,618.07	mg/kg			
100		2.78				
104	NA+K-CL~	200.00	Meq/kg	200.00	300.00	-0.2616
107	Sodium	0.20	Pct	0.20	0.20	-0.1628
108	Potassium	0.79	Pct			
109	Chloride	0.32	Pct			
112	Manganese	171.34	mg/kg			
113	Iron	241.55	mg/kg			
114	Copper	8.32	mg/kg			
115	Zinc	155.94	mg/kg			
116	Selenium	0.31	mg/kg			

APPENDIX B

INTENSIVE MULTI-PHASE NUTRIENT PROFILES

Nutrient profiles from day 1 to day 10 for Chapter IV

Agristat Data I (Treatment 1)

Nutrient	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10
ME	3063	3063	3063	3063	3063	3063	3063	3063	3063	3063
CP	22.83	22.83	22.83	22.83	22.83	22.83	22.83	22.83	22.83	22.83
Arg	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Lys	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23
TSAA	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Trp	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Thre	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
Ca	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89
Av P	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43

Agristat Data Multi-phase (Treatment 2)

Nutrient	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10
ME	3044	3044	3044	3051	3051	3051	3057	3057	3057	3063
CP	23.73	23.73	22.73	23.49	23.49	23.49	23.25	23.25	23.25	23.01
Arg	1.58	1.58	1.58	1.55	1.55	1.55	1.53	1.53	1.53	1.50
Lys	1.30	1.30	1.30	1.28	1.28	1.28	1.25	1.25	1.25	1.23
TSAA	0.94	0.94	0.94	0.93	0.93	0.93	0.93	0.93	0.93	0.92
Trp	0.25	0.25	0.25	0.25	0.25	0.25	0.24	0.24	0.24	0.24
Thre	0.88	0.88	0.88	0.87	0.87	0.87	0.85	0.85	0.85	0.84
Ca	0.93	0.93	0.93	0.92	0.92	0.92	0.90	0.90	0.90	0.89
Av P	0.45	0.45	0.45	0.44	0.44	0.44	0.44	0.44	0.44	0.43

EFG Model (Treatment 3)

Nutrient	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10
ME	3117	3117	3117	3126	3126	3126	3135	3135	3135	3144
CP	25.9	25.9	25.9	25.13	25.13	25.13	24.36	24.36	24.36	23.59
Arg	1.56	1.56	1.56	1.50	1.50	1.50	1.47	1.47	1.47	1.41
Lys	1.64	1.64	1.64	1.56	1.56	1.56	1.48	1.48	1.48	1.41
TSAA	0.78	0.78	0.78	0.77	0.77	0.77	0.76	0.76	0.76	0.75
Met	0.57	0.57	0.57	0.55	0.55	0.55	0.53	0.53	0.53	0.51
Trp	0.24	0.24	0.24	0.23	0.23	0.23	0.22	0.22	0.22	0.21
Thre	0.95	0.95	0.95	0.92	0.92	0.92	0.89	0.89	0.89	0.86
Ca	0.94	0.94	0.94	0.92	0.92	0.92	0.91	0.91	0.91	0.89
Av P	0.46	0.46	0.46	0.45	0.45	0.45	0.44	0.44	0.44	0.43

Nutrient profiles from day 11 to day 20 for Chapter IV

Agristat Data I (Treatment 1)

Nutrient	Day 11	Day 12	Day 13	Day 14	Day 15	Day 16	Day 17	Day 18	Day 19	Day 20
ME	3063	3063	3063	3063	3063	3063	3063	3063	3063	3063
CP	22.83	22.83	22.83	22.83	22.83	22.83	22.83	22.83	22.83	22.83
Arg	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Lys	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23
TSAA	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Trp	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Thre	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
Ca	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89
Av P	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43

Agristat Data Multi-phase (Treatment 2)

Nutrient	Day 11	Day 12	Day 13	Day 14	Day 15	Day 16	Day 17	Day 18	Day 19	Day 20
ME	3063	3063	3077	3077	3077	3090	3090	3090	3104	3104
CP	23.01	23.01	22.77	22.77	22.77	22.53	22.53	22.53	22.29	22.29
Arg	1.50	1.50	1.47	1.47	1.47	1.44	1.44	1.44	1.42	1.42
Lys	1.23	1.23	1.21	1.21	1.21	1.18	1.18	1.18	1.16	1.16
TSAA	0.92	0.92	0.91	0.91	0.91	0.90	0.90	0.90	0.89	0.89
Trp	0.24	0.24	0.24	0.24	0.24	0.23	0.23	0.23	0.23	0.23
Thre	0.84	0.84	0.83	0.83	0.83	0.81	0.81	0.81	0.80	0.80
Ca	0.89	0.89	0.88	0.88	0.88	0.87	0.87	0.87	0.85	0.85
Av P	0.43	0.43	0.42	0.42	0.42	0.42	0.42	0.42	0.41	0.41

EFG Model (Treatment 3)

Nutrient	Day 11	Day 12	Day 13	Day 14	Day 15	Day 16	Day 17	Day 18	Day 19	Day 20
ME	3144	3144	3152	3152	3152	3161	3161	3161	3170	3170
CP	23.59	23.59	22.82	22.82	22.82	22.05	22.05	22.05	21.28	21.28
Arg	1.41	1.41	1.34	1.34	1.34	1.29	1.29	1.29	1.24	1.24
Lys	1.41	1.41	1.34	1.34	1.34	1.28	1.28	1.28	12.2	1.22
TSAA	0.75	0.75	0.74	0.74	0.74	0.73	0.73	0.73	0.72	0.72
Met	0.51	0.51	0.48	0.48	0.48	0.46	0.46	0.46	0.44	0.44
Trp	0.21	0.21	0.21	0.21	0.21	0.20	0.20	0.20	0.19	0.19
Thre	0.86	0.86	0.84	0.84	0.84	0.81	0.81	0.81	0.78	0.78
Ca	0.89	0.89	0.88	0.88	0.88	0.86	0.86	0.86	0.85	0.85
Av P	0.43	0.43	0.42	0.42	0.42	0.41	0.41	0.41	0.40	0.40

Nutrient profiles from day 21 to day 30 for Chapter IV

Agristat Data I (Treatment 1)

Nutrient	Day 21	Day 22	Day 23	Day 24	Day 25	Day 26	Day 27	Day 28	Day 29	Day 30
ME	3063	3140	3140	3140	3140	3140	3140	3140	3140	3140
CP	22.83	20.76	20.76	20.76	20.76	20.76	20.76	20.76	20.76	20.76
Arg	1.5	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34
Lys	1.23	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
TSAA	0.92	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
Trp	0.24	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Thre	0.84	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
Ca	0.89	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82
Av P	0.43	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39

Agristat Data Multi-phase (Treatment 2)

Nutrient	Day 21	Day 22	Day 23	Day 24	Day 25	Day 26	Day 27	Day 28	Day 29	Day 30
ME	3104	3117	3117	3117	3131	3131	3131	3144	3144	3144
CP	22.29	22.05	22.05	22.05	21.81	21.81	21.81	21.57	21.57	21.57
Arg	1.42	1.39	1.39	1.39	1.36	1.36	1.36	1.32	1.32	1.32
Lys	1.16	1.14	1.14	1.14	1.12	1.12	1.12	0.99	0.99	0.99
TSAA	0.89	0.88	0.88	0.88	0.88	0.88	0.88	0.86	0.86	0.86
Trp	0.23	0.23	0.23	0.23	0.22	0.22	0.22	0.22	0.22	0.22
Thre	0.80	0.78	0.78	0.78	0.77	0.77	0.77	0.75	0.75	0.75
Ca	0.85	0.84	0.84	0.84	0.83	0.83	0.83	0.81	0.81	0.81
Av P	0.41	0.40	0.40	0.40	0.39	0.39	0.39	0.39	0.39	0.39

EFG Model (Treatment 3)

Nutrient	Day 21	Day 22	Day 23	Day 24	Day 25	Day 26	Day 27	Day 28	Day 29	Day 30
ME	3170	3179	3179	3179	3184	3184	3184	3190	3190	3190
CP	21.28	20.50	20.50	20.50	20.39	20.39	20.39	20.28	20.28	20.28
Arg	1.24	1.21	1.21	1.21	1.17	1.17	1.17	1.13	1.13	1.13
Lys	1.22	1.18	1.18	1.18	1.13	1.13	1.13	1.09	1.09	1.09
TSAA	0.72	0.71	0.71	0.71	0.69	0.69	0.69	0.67	0.67	0.67
Met	0.44	0.42	0.42	0.42	0.41	0.41	0.41	0.39	0.39	0.39
Trp	0.19	0.18	0.18	0.18	0.18	0.18	0.18	0.17	0.17	0.17
Thre	0.78	0.75	0.75	0.75	0.73	0.73	0.73	0.71	0.71	0.71
Ca	0.85	0.83	0.83	0.83	0.81	0.81	0.81	0.79	0.79	0.79
Av P	0.40	0.39	0.39	0.39	0.38	0.38	0.38	0.37	0.37	0.37

Nutrient profiles from day 31 to day 40 for Chapter IV

Agristat Data I (Treatment 1)

Nutrient	Day 31	Day 32	Day 33	Day 34	Day 35	Day 36	Day 37	Day 38	Day 39	Day 40
ME	3140	3140	3140	3140	3140	3180	3180	3180	3180	3180
CP	20.76	20.76	20.76	20.76	20.76	20.11	20.11	20.11	20.11	20.11
Arg	1.34	1.34	1.34	1.34	1.34	1.15	1.15	1.15	1.15	1.15
Lys	1.1	1.1	1.1	1.1	1.1	0.94	0.94	0.94	0.94	0.94
TSAA	0.87	0.87	0.87	0.87	0.87	0.75	0.75	0.75	0.75	0.75
Trp	0.22	0.22	0.22	0.22	0.22	0.18	0.18	0.18	0.18	0.18
Thre	0.76	0.76	0.76	0.76	0.76	0.68	0.68	0.68	0.68	0.68
Ca	0.82	0.82	0.82	0.82	0.82	0.74	0.74	0.74	0.74	0.74
Av P	0.39	0.39	0.39	0.39	0.39	0.35	0.35	0.35	0.35	0.35

Agristat Data Multi-phase (Treatment 2)

Nutrient	Day 31	Day 32	Day 33	Day 34	Day 35	Day 36	Day 37	Day 38	Day 39	Day 40
ME	3155	3155	3155	3165	3165	3165	3176	3176	3176	3188
CP	21.33	21.33	21.33	21.11	21.11	21.11	20.87	20.87	20.87	20.63
Arg	1.27	1.27	1.27	1.22	1.22	1.22	1.17	1.17	1.17	1.13
Lys	0.98	0.98	0.98	0.96	0.96	0.96	0.95	0.95	0.95	0.93
TSAA	0.83	0.83	0.83	0.79	0.79	0.79	0.76	0.76	0.76	0.74
Trp	0.21	0.21	0.21	0.19	0.19	0.19	0.18	0.18	0.18	0.18
Thre	0.73	0.73	0.73	0.71	0.71	0.71	0.69	0.69	0.69	0.67
Ca	0.79	0.79	0.79	0.77	0.77	0.77	0.75	0.75	0.75	0.73
Av P	0.38	0.38	0.38	0.36	0.36	0.36	0.35	0.35	0.35	0.34

EFG Model (Treatment 3)

Nutrient	Day 31	Day 32	Day 33	Day 34	Day 35	Day 36	Day 37	Day 38	Day 39	Day 40
ME	3195	3195	3195	3200	3200	3200	3206	3206	3206	3211
CP	20.17	20.17	20.17	20.06	20.06	20.06	19.95	19.95	19.95	19.84
Arg	1.09	1.09	1.09	0.05	0.05	0.05	1.0.1	1.01	1.0.1	0.98
Lys	1.04	1.04	1.04	1.00	1.00	1.00	0.97	0.97	0.97	0.93
TSAA	0.65	0.65	0.65	0.64	0.64	0.64	0.62	0.62	0.62	0.60
Met	0.38	0.38	0.38	0.36	0.36	0.36	0.35	0.35	0.35	0.34
Trp	0.17	0.17	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.15
Thre	0.69	0.69	0.69	0.67	0.67	0.67	0.65	0.65	0.65	0.63
Ca	0.78	0.78	0.78	0.76	0.76	0.76	0.75	0.75	0.75	0.74
Av P	0.36	0.36	0.36	0.35	0.35	0.35	0.34	0.34	0.34	0.33

Nutrient profiles from day 41 to day 49 for Chapter IV

Agristat Data I (Treatment 1)

Nutrient	Day 41	Day 42	Day 43	Day 44	Day 45	Day 46	Day 47	Day 48	Day 49
ME	3180	3180	3208	3208	3208	3208	3208	3208	3208
CP	20.11	20.11	20.10	20.10	20.10	20.10	20.10	20.10	20.10
Arg	1.15	1.15	1.09	1.09	1.09	1.09	1.09	1.09	1.09
Lys	0.94	0.94	0.89	0.89	0.89	0.89	0.89	0.89	0.89
TSAA	0.75	0.75	0.72	0.72	0.72	0.72	0.72	0.72	0.72
Trp	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
Thre	0.68	0.68	0.64	0.64	0.64	0.64	0.64	0.64	0.64
Ca	0.74	0.74	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Av P	0.35	0.35	0.31	0.31	0.31	0.31	0.31	0.31	0.31

Agristat Data Multi-phase (Treatment 2)

Nutrient	Day 41	Day 42	Day 43	Day 44	Day 45	Day 46	Day 47	Day 48	Day 49
ME	3188	3188	3200	3200	3200	3210	3210	3210	3214
CP	20.63	20.63	20.39	20.39	20.39	20.15	20.15	20.15	20.02
Arg	1.13	1.13	1.11	1.11	1.11	1.08	1.08	1.08	1.06
Lys	0.93	0.93	0.90	0.90	0.90	0.88	0.88	0.88	0.87
TSAA	0.74	0.74	0.73	0.73	0.73	0.72	0.72	0.72	0.71
Trp	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
Thre	0.67	0.67	0.65	0.65	0.65	0.63	0.63	0.63	0.62
Ca	0.73	0.73	0.71	0.71	0.71	0.70	0.70	0.70	0.68
Av P	0.34	0.34	0.32	0.32	0.32	0.30	0.30	0.30	0.29

EFG Model (Treatment 3)

Nutrient	Day 41	Day 42	Day 43	Day 44	Day 45	Day 46	Day 47	Day 48	Day 49
ME	3211	3211	3216	3216	3216	3221	3221	3221	3225
CP	19.84	19.84	19.73	19.73	19.73	19.62	19.62	19.62	19.55
Arg	0.98	0.98	0.96	0.96	0.96	0.93	0.93	0.93	0.91
Lys	0.93	0.93	0.92	0.92	0.92	0.88	0.88	0.88	0.87
TSAA	0.60	0.60	0.58	0.58	0.58	0.56	0.56	0.56	0.55
Met	0.34	0.34	0.32	0.32	0.32	0.31	0.31	0.31	0.30
Trp	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.14	0.14
Thre	0.63	0.63	0.60	0.60	0.60	0.58	0.58	0.58	0.57
Ca	0.74	0.74	0.72	0.72	0.72	0.71	0.71	0.71	0.70
Av P	0.33	0.33	0.33	0.33	0.33	0.32	0.32	0.32	0.31

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