Nutritional Intervention in the Early Growing Broiler Chick

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TABLE OF CONTENTS

Page

CHAPTERS

2. LITERATURE REVIEW

LIST OF TABLES

Table Page

CHAPTER 1

INTRODUCTION

The first week of life for broilers and turkeys has become an increasingly important nutritional and managerial consideration as it continually accounts for a larger portion of the total growing period (Lilburn, 1998; Geyra et al., 2001; Willemsen et al., 2008; Tancharoenrat et al., 2013; Ebling et al., 2015). The reason it accounts for a larger portion of the total growing period is due to the remarkable improvements in poultry genetics allowing today’s common broilers and turkeys to reach a much heavier weight at a younger age, thus decreasing the age at slaughter (Havenstein et al., 2003b; Havenstein et al., 2007). Broilers are now commonly slaughtered between 36 and 56 days of age (DOA), hence the first two weeks of life accounts for about 28% of the average broilers lifetime. Despite accounting for 28% of time, the first two weeks of life account for less than 9% of total feed consumption (Cobb-Vantress, 2015) making this period an ideal time to use more expensive ingredients to boost performance (Lilburn, 1998; Ebling et al., 2015). Ferket (2015) suggested that perinatal and immediate post-hatch nutrition may be constraining development necessary to support subsequent growth. If correct, early nutrition strategies have the potential to improve growth and livability through to marketing.

Differences in growth, due to treatment, have been noted at 7-14 DOA and still seen at marketing after all birds were placed on common diets (Noy and Sklan, 1999a; Sklan and Corbett, 2003; Campbell et al., 2006). In agreement, Willemsen et al. (2008) found body weight (BW) at 7 DOA to be the best predictor of BW at 42 DOA with a correlation of about 0.43. Based on this research, it should be possible to improve growth during the first 1-2 weeks and still notice improvements at market.

Intense changes in the small intestine of the bird immediately post-hatch (Lilburn, 1998; Geyra et al., 2001) provide the opportunity to improve growth throughout the life of the bird by adjusting nutrition in the first week. Immediately post-hatch, the bird must adapt to utilization of exogenous feed rather than yolk (Noy and Sklan, 2001) and the small intestine doubles in weight almost twice as fast as the rest of the body (Sklan, 2001). Improving the health of the gut and better meeting the nutritional requirements of the bird may improve the gut's effectiveness at digesting and absorbing nutrients throughout the life of the bird, resulting in improved feed conversion or BW gain.

Studies have provided evidence that young chicks have a low physiological capacity to digest and absorb fats (Renner and Hill, 1961; Carew et al., 1972; Krogdahl, 1985; Sell et al., 1986; Tancharoenrat et al., 2013). This has created a dogma within poultry nutrition that dietary lipids should not be utilized in young poultry (Lilburn, 1998). Although the low capacity to digest and absorb fats may be somewhat true, starch and nitrogen digestibility are also lower in the young chick than at any point later in life (Noy and Sklan, 1995). As Lilburn (1998) notes, the use of dietary fat should not be avoided because the yolk is primarily made of fatty acids and thus the metabolic machinery of young poultry are outfitted to oxidize fatty acids. The addition of high amounts of fat in the diet of young birds will increase nutrient density of the diet and possibly improve digestibility and absorption of nutrients (Firman and Remus, 1994), thus enhancing growth and intestinal health.

The addition of spray dried plasma protein (SDPP) in the diets of young chicks is another strategy for improving gut health and growth performance. The swine industry commonly uses SDPP as a protein source for the starter diets of early weaned pigs due to improved intake and reduced growth lag post-weaning (Bregendahl et al., 2005b; Pierce et al., 2005). It is thought that a similar response could be found in poultry and SDPP could be similarly used during the first 1-2 weeks post-hatch. SDPP has been shown to have positive effects on growth and livability in broilers and turkeys, but effects are primarily noted when birds are in high pathogen environments (Campbell et al., 2003; Campbell et al., 2004; Bregendahl et al., 2005a; Bregendahl et al., 2005b; Campbell et al., 2006). Campbell and coworkers (2006) found improved livability and growth parameters in broilers fed SDPP to 14 DOA when challenged with Escherichia coli and Salmonella.

Lilburn (1998) and Ebling and coworkers (2015) suggested that early intervention strategies should be seen as an investment and an ideal time to use more expensive ingredients to improve growth parameters throughout the life of the bird. I would suggest early intervention strategies may be seen as insurance in which growers pay a small premium during the first 1-2 weeks to insure good health and performance in case of a disease challenge or other negative stressor.

CHAPTER 2

LITERATURE REVIEW

INTRODUCTION

Tremendous progress has been made in poultry growth and efficiency over the last 60 plus years. Havenstein et al. (2003b) reported that, at 56 days of age (DOA), a common broiler from 2001 on common feed for the time weighed 4.88 times as much and converted feed 0.56 kg feed/kg gain better than birds common to 1957 on feed common for the time. Hot carcass weight was 5.86 times greater in year 2001 birds than in year 1957 birds (Havenstein et al., 2003a) and similar results were found in the turkey (Havenstein et al., 2007). Even in 1976, Nir and coworkers (1978) noted the improved, high capacity of the broiler to eat and grow. Havenstein and coworkers (2003b) determined that genetic selection accounted for about 85-90% of improvement in broiler growth rate while nutrition accounted for 10-15% of improvement. The improvement in poultry nutrition was primarily driven by the need to sustain the improvement in genetic potential as the overall goal of poultry nutrition is to lower feed costs and maximize economic efficiency (Ravindran, 2012). With this in mind it is important for us, as nutritionists, to realize that as genetic potential continually improves, the time to market continually decreases, making the first week of life a larger portion of the total growing period and early nutrition an even more important consideration (Lilburn, 1998; Geyra et al., 2001; Willemsen et al., 2008; Tancharoenrat et al., 2013; Ebling et al., 2015). Ferket (2015) reported that the incubation and neonatal period account for about 50% of the broilers productive life and we may need to meet these requirements better to achieve full expression of genetic potential.

The first two weeks of life accounts for 28% of a seven week broiler's life but only accounts for about 8.5% of total feed consumption (Cobb-Vantress, 2015). This low amount of total feed intake (FI) makes the first two weeks of life an opportune time to use more expensive ingredients to boost performance (Lilburn, 1998; Ebling et al., 2015). At current prices of about $220/ton and $200/ton in the pre-starter and finisher rations, respectively, an 8% increase in the price of the pre-starter ration would have to occur to raise the total cost of feed/bird 1 cent (CME, 2015; Cobb-Vantress, 2015). This calculation would be assuming the increase in diet cost caused no improvements in feed efficiency and thus demonstrates the potential for cheaply improving the growth and efficiency of broilers. Feed costs represent about 70% of the cost of poultry production (Willems et al., 2013). Mathematically speaking, manipulating feed formulation to improve feed efficiency or reducing cost/ton have the greatest potential to decrease cost of production.

The poultry industry currently uses many ingredient addition, mixing, and feed formulation techniques to improve poultry growth as well as decrease cost of the diet. Crystalline amino acids (AA) are commonly used to more precisely meet the ideal AA profile (Waldroup et al., 1976; Ravindran, 2012). Fats and oils are routinely added to increase energy concentration (Dozier et al., 2006b; Firman, 2006; Vieira et al., 2015) and achieve rapid growth potential (Tancharoenrat et al., 2012). Essential AA and energy are the most expensive dietary components (Dozier et al., 2007a; Ravindran, 2012), thus precisely meeting AA requirements with crystalline AA lowers the total cost of the diet.

Use of fats allows us to increase ME to levels we would otherwise be unable to achieve. Diets containing a high energy content can become very expensive though and so the energy level is frequently an economic decision (Plavnik et al., 1997).

Poultry diets commonly contain up to 50% starch on a dry matter (DM) basis as poultry have a high capacity to digest starch (Svihus, 2014). Corn and soybean meal (SBM) are the major ingredients in most U.S. poultry diets. Enzymes are commonly employed to economically increase utilization of nutrients already in the diet (Ravindran, 2012; Ravindran, 2013; Stefanello et al., 2015). Diets are also commonly pelleted to improve poultry performance and efficiency (McNaughton and Reece, 1984a; Ravindran, 2012)

Poultry feed formulation is most commonly done by way of least-cost, computer formulation. The computer calculates the cheapest possible option of ingredient addition to meet your nutrient and ingredient constraints (Ravindran, 2012). A minimum of 1% fat is commonly maintained for purposes of pelleting, dust reduction, equipment lubrication, and improved palatability without regard to cost of fat (Firman, 2006). Feed formulation is commonly based on digestible nutrients and the ideal protein concept to allow more precise feeding of nutrient requirements and facilitate the use of by-products (Ravindran, 2012). Requirements for feed formulation have historically come from the National Research Council (NRC) but the most recent NRC publication (NRC, 1994) was released in 1994 and is essentially out of date given the recent genetic advancements. Recommendations from breeding companies more closely match requirements of modern bird strains (Ravindran, 2012; Trevisan et al., 2014).

ECONOMIC FEASIBILITY

In the years 2001 and 2015, the average price of fats and oils was 17 and 43 cents/lb. respectively (ERS, 2015). Feed prices are generally headed upward and becoming more variable due to increased ethanol and biofuel production among other reasons (Dozier et al., 2007a; Donohue and Cunningham, 2009; Willems et al., 2013; Ferket, 2015). Historically, prices in the U.S. are primarily dependent on U.S. production of the commodity that year. By-product prices historically follow that of corn and SBM and thus as the demand and cost of corn and SBM increases, so does the cost and demand for by-products (Donohue and Cunningham, 2009). Increased demand for fats in biofuel production has caused a rise in fat prices in relation to corn (Donohue and Cunningham, 2009) causing the cost of dietary energy to consistently increase (Vieira et al., 2015).

Donohue and Cunningham (2009) determined that every $0.10/bushel increase in corn adds $0.001 in feed ingredient expenses/lb. of live weight produced and every $10.00/ton increase in SBM adds $0.001 in feed ingredient expenses/lb. of live weight produced. Because feed costs represent about 70% of cost of poultry production (Willems et al., 2013), ingredient market fluctuations is one of the greatest risks to profitability in poultry production. An increase in feed cost makes feed conversion even more important (Donohue and Cunningham, 2009; Willems et al., 2013). For both broilers and turkeys, as feed prices increase the economic costs of feed consumption and mortality increase causing the economic value of finishing weight to decrease and the economic value of feed conversion to increase (Jiang et al., 1998; Wood, 2009). As Willems and coworkers (2013) discussed that a 100,000 broilers/cycle farm, with a 2.00 feed conversion ratio (FCR), would experience about a $165,000 rise in annual feed cost due to a 30% increase in feed prices. In this example, if FCR was only 0.01 better at 1.99 the annual feed cost would be $701,475 as compared to $705,000 at 2.00 FCR. Over the expanse of the entire poultry industry this saving would be substantial.

In the interest of improving FCR over the life of the bird, combinations of high energy, high digestibility, and high protein ingredients could be used during the first 7-10 days to meet the high needs of the young poult or chick and should be viewed as an investment rather than a cost. (Lilburn, 1998; Ebling et al., 2015). Ferket (2015) suggests that advancements in perinatal and neonatal nutrition are necessary for full expression of genetic potential in poultry. Multiple experiments would support this theory, presenting data that the first week posthatch is a critical period for overall intestinal growth (Dibner et al., 1996; Lilburn, 1998; Geyra et al., 2001; Iji et al., 2001a, b).

Willemsen and coworkers (2008) reported that bird body weight (BW) at 7 days of age (DOA) to be the best predictor of BW at 42 DOA. This suggests improvement of BW during the first week of life can positively influence market BW. In agreement, a review by Sklan and Corbett (2003) supports that proper nutrition close to hatch can have lasting results through to market. Risk of rising costs, low feed consumption during the first week of life, and the impact of 7 day weight on market weight make advancements in early poultry nutrition an economically advantageous option.

RESPONSE TO DIETARY METABOLIZABLE ENERGY CHANGES

Robbins and Firman (2006) found there to be no consistent differences between apparent metabolizable energy (AME) and total metabolizable energy (TME) values. Pooled metabolizable energy (ME) values of roosters, broilers, and turkeys were also found to be insignificantly different and thus feed ingredient's ME values can be applied to broilers and turkeys independent of the species in which the ME was determined (Dale and Fuller, 1980a; Robbins and Firman, 2006). Based on these data, research using ME, AME, or TME values will be discussed interchangeably.

From a research standpoint, it is important to keep in mind whether you are testing a change in ME or a change in fat when increasing the level of fat. Increasing ME is most commonly done by the addition of fat (Dozier et al., 2006b; Firman, 2006; Vieira et al., 2015) making the impact of fat or ME difficult to discern. From an industry application standpoint, it is important to consider the practical considerations of cost of the diet and use in equipment. Generally, 8-10% inclusion is considered maximum addition of fat due to physical limitations of feed above this inclusion rate (Firman, 2006). Research above this 10% fat inclusion may be applicable to discerning the impact of fat and ME but the data is not applicable for use in practical poultry diets.

It is beneficial to test within a small, practical range of ME such as (Dozier et al., 2011) testing 3140-3240 kcal/kg with 20 kcal/kg increments but this presents the issue brought about by (Firman et al., 2008) that a 3160 kcal/kg diet has only 0.6% more energy than a 3140 kcal/kg diet and this level of difference is realistically impossible to detect. In addition, differences in calculated ME and tested ME of diets fed can be as much as 45-125 kcal/kg in one experiment or 0-26 kcal/kg in another experiment conducted back to back at the same location (Dozier et al., 2011) making the impact of ME even more difficult from which to draw conclusions.

Response to ME can be affected by both sex and temperature due to a combination of intake regulation and metabolic factors (Dozier et al., 2011) but data is unclear how all these variabilities interact. Zhai and coworkers (2014) and Ravindran and coworkers (2016) concluded that inconsistencies in response to AME levels and theory of intake regulation may be due to a combination of factors including strain, sex, age, varying nutrient levels and their interactions, environmental conditions, and management techniques. These inconsistencies between experimental methods and conditions combined with significant genetic advancements (Havenstein et al., 2003b; Havenstein et al., 2007) makes comparison between studies difficult and often inconclusive. Dozier and coworkers (2007b) formulated equations to predict BW based on AME of diet and days of age, but the authors admit the equations are only valid for that specific experiment because there were so many variables.

Intake Regulation:

Regulation of feed intake (FI) is an important consideration when attempting to improve BW gain and FCR. The most prominent theory of FI regulation is that FI and diet ME are negatively correlated (Leeson and Atteh, 1995; Leeson et al., 1996; McKinney and Teeter, 2004; Dozier et al., 2006b; Dozier et al., 2007b). Other studies have reported FI to not be commensurate with change in nutrient density, suggesting birds are not maintaining isocaloric consumption (Brue and Latshaw, 1985; Saleh et al., 2004b, a).

Feed intake was regulated by energy when CP was constant across treatments (Leeson et al., 1996; Dozier et al., 2006b) and when an energy:CP ratio was maintained (Dozier et al., 2007b). Similarly FI was constant when CP was constant across treatments (Brue and Latshaw, 1985) and when an energy:CP ratio was maintained (Saleh et al., 2004b, a).

Feed intake regulation may be dependent on the age of the birds as well as the ME content of the diet. Noy and Sklan (1995) reported that in the young chick, FI roughly met the enzymatic capacity of the gut, suggesting that FI is regulated to not exceed the chick's digestive capability. Similarly (Jiménez-Moreno et al., 2015) suggested that young chicks may compensate for lower nutrient digestibility by improving feed utilization because FI, FCR, and growth remained the same despite varying levels of nutrient density. In the young chick, FI may be regulated by fill due to the low capacity of the gut up to a dietary ME concentration, over which energy may become the regulating factor.

Saleh and coworkers (2004b) suggested that the modern broiler has been selected to consume feed at almost full capacity regardless of ME content. This theory may be partially true in that there is not perfect regulation of FI to maintain isocaloric consumption (Ferket and Leeson, 2014). In the same study, Saleh and coworkers (2004b) noted that feed intake was reduced with increasing nutrient density, but it was not equivalent to the increase in ME and so isocaloric consumption was not maintained. This non-perfect regulation of FI by ME content is most likely correct but confounded by the many variables listed above (Zhai et al., 2014; Ravindran et al., 2016). This is apparent in McKinney and Teeter (2004) study where FI generally decreased and energy consumption generally increased with increasing ME concentration, but significance was not found between each treatment.

Energy:CP ratio:

Considering the bird may adjust FI to dietary energy content, it is important to maintain a consistent energy:CP ratio to insure proper growth. Since birds actually require AA (NRC, 1994), a consistent energy:AA ratio is even more vital. Dozier and coworkers (2008) did not adjust AA concentration with increasing AME in fear of confounding effects. Not adjusting AA concentration is confounding though since a bird that is eating less due to increased energy would also be consuming less AA and possibly limiting its growth (Leeson et al., 1996). In agreement, Sell and Owings (1981) found that protein adjusted and non-adjusted diets both improved feed efficiency with increasing ME levels but only the adjusted improved BW gain.

Not maintaining an energy:CP or AA ratio has been reported to have negative effects on lean tissue growth and increase the fat pad (Donaldson et al., 1956; Leeson et al., 1996; Trevisan et al., 2014). Dozier and coworkers (2006b; 2007a) also found that increasing AME without adjusting CP caused decreased breast meat yield and suggested this is because the bird ate less feed due to increased energy content and thus did not consume enough CP, primarily lysine. When authors increased CP and AA with energy, breast meat yield and carcass fatness was unaffected (Fuller and Rendon, 1977; Plavnik et al., 1997; Saleh et al., 2004b, a; Dozier et al., 2007b) or breast meat yield improved (Dozier et al., 2006a).

Practical Metabolizable Energy Range:

Total energy consumption, growth, and FCR generally improve with increasing nutrient density but there may be a range in which this is true with upper and lower limits (McKinney and Teeter, 2004). Saleh and coworkers (2004b) found BW and FCR to improve with increasing ME until a plateau of about 3250 kcal/kg at which point they were less efficient. The authors also found that in finishing birds, the extent of BW and FCR improvement diminished as ME increased. McKinney and Teeter (2004) suggests there is a plateau at 3066 kcal/kg at which point FCR may continue to improve but sellable lean tissue does not improve and carcass fat increases. Similarly, carcass weight was generally unaffected from 3023-3304 kcal/kg before decreasing at 3344 and 3383 kcal/kg (Saleh et al., 2004b).

In some cases, dietary energy content has been shown to have no significant effects on BW, FCR, or fat pad (Waldroup et al., 1990). Based on this and the many variabilities impacting nutrient utilization (Zhai et al., 2014; Ravindran et al., 2016), AME should be formulated based on company history, shadow prices, temperature set points (Dozier et al., 2007b), and current research that is applicable to your specific situation.

EARLY INTERVENTION

Combinations of high energy, high digestibility, and high protein ingredients could be used during first 7-10d to meet the high needs of the young poult or chick and should be viewed as an investment rather than a cost (Lilburn, 1998; Ebling et al., 2015). To achieve optimal nutrition during the first week, nutritional contributions from the yolk and the chick's ability to utilize exogenous feed should be taken into account (Lilburn, 1998; Noy and Sklan, 2002). When exogenous FI begins, chicks must adapt from yolk dependence to utilization of the exogenous feed (Noy and Sklan, 2001). Immediately after hatch, intense changes in the small intestine (SI) occur as the SI increases in weight almost twice as fast as the rest of the body (Sklan, 2001).

As Lilburn and Loeffler (2015) note, there has been widespread commercial acceptance of *in ovo* delivery of vaccines within the last 20 years which has created interest in the *in ovo* delivery of nutrients to improve intestinal growth and development.

Multiple studies have reported improved intestinal functions in the immediate post-hatch chick as reviewed by Lilburn and Loeffler (2015). Tako et al. (2004) found the *in ovo* delivery of carbohydrates (CHO) and *β*-hydroxy-*β*-methylbutyrate improved intestinal function and resulted in larger 10 d BW when the experiment ended. This suggests there is potential for improving final BW by improving early nutrition.

Yolk Utilization:

During the first 48 hours posthatch, yolk weight declined exponentially with fed birds decreasing more rapidly than birds withheld feed during the first 48 hours (Noy and Sklan, 1999b; Sklan and Noy, 2000; Noy and Sklan, 2001). Weight and length of the SI increased at greater rate than BW until 5-7 d posthatch of chicks (Noy and Sklan, 1999b; Sklan and Noy, 2000) and turkeys (Uni et al., 1999). Feed-deprived chicks SI weight and length grew at greater rate than BW, but all together not as much as fed chicks, indicating that yolk is in part used for intestinal growth (Noy and Sklan, 1999b; Sklan and Noy, 2000). Noy and Sklan (1999b) also found the maintenance requirement of chicks during the first 48 hours posthatch is about 4.5 kcal per day for a 45 g bird at 32°C. Considering chicks can survive on yolk for 72 hours posthatch (Noy et al., 1996) this clearly shows the input of the yolk and why optimal first week nutrition must take into account contribution from the yolk (Lilburn, 1998; Noy and Sklan, 2002).

Yolk can be utilized in the young chick either via endocytosis directly into the circulation (Lambson, 1970) or by transportation through the yolk stalk to the intestine (Esteban et al., 1991). Appearance of exogenous material in the gastrointestinal tract (GIT) stimulates the release of yolk through the yolk stalk (Noy and Sklan, 2001). The yolk is comprised of about 50% lipids at hatch, primarily acylglycerides (Noy and Sklan, 2001). This indicates, and as Lilburn (1998) states, the metabolic machinery of young poultry are outfitted to oxidize fatty acids (FA) making the use of FA for energy appear to be a good idea. In agreement, Turner et al. (1999) found turkeys fed a high fat diet to be heavier and more feed efficient at 13 DOA than turkeys fed CHO diets, suggesting that supplemental fat may ease the metabolic shift to glycolysis after hatch.

Gastrointestinal Tract Development:

The first week posthatch is a critical period for overall intestinal growth (Dibner et al., 1996; Lilburn, 1998; Geyra et al., 2001; Iji et al., 2001a, b). In the first 24 hours posthatch enterocytes acquired polarity and a distinct brush-border membrane. After the first 24 hours, hypertrophy then began to occur primarily in the form of increased cell length. Little hypertrophy occurred in the ileum after 24 hours while hypertrophy of enterocytes continued in the duodenum and jejunum until 216 and 144 hours posthatch, respectively (Geyra et al., 2001). Length increased more rapidly in jejunum and ileum, while mass increased more in the duodenum and jejunum, and pancreas increased in mass relative to BW (Uni et al., 1999).

Geyra et al. (2001) found total absorptive area to be similar in all SI segments at hatch and grew similarly to 72 hours posthatch. At 72 hours posthatch, jejunal absorptive area grew much larger, plateauing at 240 hours posthatch. Surface area represents absorptive potential but actual uptake depends on substrate, carrier, and transporter concentrations as well as turnover rates (Geyra et al., 2001). From their study, Geyra et al. (2001) suggested that intestinal surface area is not limiting absorption in the young chick.

Feed consumption increased threefold while rate of passage decreased 30% in 4-10 d posthatch. After 10 d, rate of passage remained the same while intake continued upward (Noy and Sklan, 1995). From 4 to 21 DOA lipase, trypsin, amylase, and total protease secretion increased 20- to 100 fold, while lipase activity increased the least of all enzymes tested in both chicks (Noy and Sklan, 1995) and turkeys (Krogdahl and Sell, 1989). At 4 DOA and using a typical corn, SBM diet with 6% Soybean oil, digestion of FA and starch was over 85% with relatively no change thereafter, suggesting there was sufficient lipase and bile salts available at 4 DOA (Noy and Sklan, 1995). Digestion of N was 78% at 4 DOA and 92% at 21 DOA (Noy and Sklan, 1995).

The duodenum and jejunum are the major sites of absorption for most nutrients (Noy and Sklan, 1995). Lipid digestion primarily occurs in the jejunum of poultry because the bile duct is in the distal duodenum loop. Digestion continues in the upper ileum (Renner, 1965; Hurwitz et al., 1973; Tancharoenrat et al., 2014) and absorption of fat is negligible in the large intestine (Renner, 1965).

Early Nutrition Intervention Impact on Final Body Weight:

As reviewed by Sklan and Corbett (2003), early proper nutrition has been shown to enhance BW gain and although the improvement in BW gain diminished with age, it was generally maintained through to market. In a popular press article, Ferket (2015) noted that ascites and sudden death syndrome appear to again be developing into a problem for the industry. Ferket (2015) suggested that the birds are not growing too fast, as it may appear, but instead under nutrition in the perinatal and immediate post-hatch nutrition are constraining development to support subsequent growth. If Ferket (2015) is correct, then early intervention strategies have the potential to not only improve BW through to marketing but also improve livability through to marketing. This line of thought and the desire to cheaply improve final BW has led to recent management technique developments, such as on farm hatching (Vencomatic, 2016), and the development of early nutrition intervention strategies.

When comparing fed versus withheld from feed and water during the first 34 hours for broilers and the first 48 hours for turkeys, significant BW and breast yield improvements were observed in both broilers and turkeys at 39 and 140 days respectively (Noy and Sklan, 1999a). Alternatively, Turner and coworkers (1999) found weight difference in fed and withheld chicks to be insignificant at 13 DOA.

A study of chick quality parameters, found BW at 7 DOA to be the best predictor of BW at 42 DOA and BW at 1 DOA to be the next best predictor among the quality measure performed (Willemsen et al., 2008). Correlation between 7 DOA BW and 42 DOA BW was .37, .38, and .54 for the 3 breeder flocks tested while correlation to 1 DOA BW was about .30. As reviewed by Willemsen and coworkers (2008), chick quality can be influenced by many factors such as breeder line, age, weight of the egg, and time in storage. Differences in chick quality could influence the success of early intervention strategies.

In an attempt to improve starch digestibility Ebling and coworkers (2015) fed rice in substitution of corn during the first 7 DOA. Weight gain was significantly improved after 7 days, but all birds were switched to a common diet after 7 days and effects were not evident at 33 DOA. Similarly, diets consisting of varying levels of fat, protein, and cellulose all had individual effects at 7 DOA but was not significant at 18 DOA (Noy and Sklan, 2002). Ebling and coworkers (2015) noted that their birds were in a near ideal environment and suggested that in commercial production, early intervention may have more of an impact on final flock performance due to greater health and thermal challenges, competition for feeder and drinker space, as well as lessened flock uniformity in a commercial setting, compared to a research environment.

In general, these studies provide evidence that early intervention strategies that improve BW at 7 DOA have the potential to improve BW at marketing.

Early Nutrition Intervention Strategies:

Multiple early nutrition intervention strategies have been researched. As mentioned above, Ebling and coworkers (2015) attempted to improve starch digestibility by replacing corn with rice. The authors also included soy protein isolate (SPI) as a partial replacement of SBM because of its high protein content and low non-starch polysaccharide content, but found SPI did not affect FI or BW gain.

The inclusion of insoluble fiber at hatch has shown minor improvements in average daily gain (ADG) and FCR during first 21 DOA (Jiménez-Moreno et al., 2009; Jiménez-Moreno et al., 2015). Both of these studies were conducted in battery cages and thus Jiménez-Moreno and coworkers (2009) suggested that in floor pens, where birds can consume litter, the need for dietary fiber may be reduced.

Although it was not their primary objective, Henn and coworkers (2013) and Campbell and coworkers (2006) studied the addition of spray-dried plasma protein (SDPP) in broilers as an early intervention strategy. In a high pathogen environment, inclusion of SDPP to 14 DOA produced similar growth promotion and improved livability as inclusion of SDPP throughout the life of the bird (Campbell et al., 2006). In a different, and presumably cleaner environment, broilers did not show improvement from either early inclusion of SDPP or inclusion throughout the life of the bird (Henn et al., 2013). These environmentally dependent results are consistent with other studies to be discussed later.

Aside from pelleting diets, providing a high plain of nutrition has been the most common and successful early nutrition intervention strategy. Feed efficiency and growth was improved in turkeys fed a high plain of nutrition via higher fat inclusion to 14 DOA and the improved BW was still significant at 14 weeks of age (Moran Jr, 1978). Similarly, fat inclusion during first 21 DOA improved BW gain and FCR of broilers (Kessler et al., 2009; Tancharoenrat and Ravindran, 2014).

Pelleting is commonly used in the industry (McNaughton and Reece, 1984a; Ravindran, 2012) for good reason as it consistently provides significant improvement in ADG, average daily feed intake (ADFI), and FCR during the starter period and through to marketing (McKinney and Teeter, 2004; Jiménez-Moreno et al., 2015).

Increased Dietary Fat as an Early Nutrition Intervention Strategy:

There have been many studies suggesting the physiological capacity to digest and absorb fats is low in young birds, especially during the first week of life (Renner and Hill, 1961; Carew et al., 1972; Krogdahl, 1985; Sell et al., 1986; Tancharoenrat et al., 2013). This premise has created a dogma within poultry nutrition that dietary lipids should not be utilized in young poultry (Lilburn, 1998). The work of Carew et al. (1972) has been the primary example supporting the avoidance of dietary lipids due to low absorption but their study used White Leghorn chicks, did not utilize industry standard corn-soy diets, and included 20% corn oil or tallow. One might suggest it is impractical to think that young poultry would have the lipase and bile production capacity to digest that much fat. In addition, the feed may stick together causing a high surface area:mass ratio of feed particles in the gut, resulting in limited enzyme access to all of the feed particles. It is also unrealistic to use 20% fat in a diet as 8-10% fat inclusion is considered to be the maximum due to physical limitations in equipment above 8-10% (Firman, 2006).

As dietary fat increased, the increased lipid intake caused a decrease in percentage lipid uptake, but absolute lipid absorption increased (Noy and Sklan, 2001). Similarly, Tancharoenrat and Ravindran (2014) found ileal digestibility and total tract retention to be lower at 8% dietary fat inclusion than 4%, but BW gain and FCR were improved at 8% fat inclusion due to increased total nutrient intake. Noy and Sklan (2001) suggested this phenomenon, and the very high dietary fat inclusion of previous experiments may explain why previous studies suggest young poultry have low lipid absorption.

As Lilburn (1998) notes, the dogma in poultry nutrition that dietary fats should be avoided in young poultry diets because they are not maximally digested is impractical because the metabolic machinery of young poultry are outfitted to oxidize FA. In agreement, Turner and coworkers (1999) found turkeys fed a high fat diet to be heavier and more feed efficient at 13 DOA than turkeys fed CHO diets, suggesting that supplemental fat may ease the metabolic shift to glycolysis after hatch.

Despite what seems to be common belief among early scientists, fats are not the only nutrients poorly absorbed in the very young chick. Carbohydrates and protein, more specifically glucose and methionine, retention were low immediately posthatch but over 80% retained by 4 d posthatch. Oleic acid retention was over 80% at hatch and remained high (Noy and Sklan, 1999b; Noy and Sklan, 2001). White leghorn chicks force-fed consumed 43% more feed than the ad lib control over an 18 day period, yet BW was only 30% more at the end of the study (Nir et al., 1978). This suggests most nutrients will not be absorbed as well when fed in extreme excess. Batal and Parsons (2002) found AA, fat, and starch digestibility all improved with age and that ME utilized by the chick improved about 100kcal/kg DM every 2-3 days until 14 DOA, primarily due to the increase in fat utilization from 60% at 0-7 DOA to 74% at 14 & 21 DOA. Likewise, starch, FA, and nitrogen digestibility were lowest during week 1 than any period later in life (Noy and Sklan, 1995). Tancharoenrat et al. (2013) also found the AME and coefficient of total tract apparent digestibility (CTTAD) of fats to almost double from week 1 to week 2. Although poor digestion of fats in young poultry appears to be real, it is not very significant from a practical standpoint since the bird shows rapid improvement in fat utilization (Firman, 2006) and total absorption is increased in high fat diets (Noy and Sklan, 2001).

In addition to age and percentage of dietary fat inclusion, digestibility of fats is also dependent on the unsaturated to saturated FA ratio (U:S) and the length of FA (Turner et al., 1999; Ravindran et al., 2016). Better FCR, fat retention, and ileal fat digestibility was obtained with soybean oil (unsaturated) compared to tallow (saturated) in broilers 1-21 DOA (Tancharoenrat et al., 2012). Noy and Sklan (1995) found 6% added soybean oil (unsaturated) digestion was over 85% at 4 DOA and was unchanged after 4 DOA, suggesting the chick is capable of maximum unsaturated FA digestion at 4 DOA. Performance characteristics were insignificant at 21, 35, and 49 DOA independent of fat source at 3% inclusion (Firman et al., 2008). Based on other studies, it is possible that unsaturated fats improved performance during the first week posthatch and these effects were diluted by 21 DOA.

Tancharoenrat and coworkers (2013) quantified AME of several fat sources in the first week post-hatch and suggested that lower AME values should be assigned to fats when formulating for diets in the first week. Although this may be technically correct, assigning lower AME values to fats during the first week would mean AME values should be reduced for all ingredients since starch digestibility is also reduced. In addition the requirements for energy, and more importantly the energy:AA ratio, must also be adjusted since current energy requirements are based on full digestibility of starch, fat, and protein.

DIETARY FAT UTILIZATION

The terms ‘fat’ and ‘oil’ refer to triacylglycerols that are either solid or liquid, respectively at room temperature (Ravindran et al., 2016) but will be collectively termed as ‘fat’ throughout this literature review. At least 1% fat is typically added for pelleting, dust reduction, equipment lubrication, and improved palatability, while 8-10% dietary fat is generally considered the maximum inclusion rate due to physical limitations of feed above 10% (Firman, 2006). According to Tancharoenrat and coworkers (2012), tallow and soybean oil are the most commonly used fat sources in the poultry industry. Yellow grease is also widely available and often the cheapest fat source. Fats routinely demonstrate energy values at least twice that of carbohydrates and protein (NRC, 1994).

As reviewed by Ravindran and coworkers (2016), fat digestion begins in the gizzard as the mechanical activity of the gizzard disperses the lipids and mixes them with bile salts and monoglycerides refluxed from the duodenum to begin fat emulsification. Negative apparent digestibility of fat and FA in the duodenum indicates the net secretion of fat in the duodenum due to bile and pancreas secretions in this section (Hurwitz et al., 1973; Tancharoenrat et al., 2014). Pancreatic lipase acts on the sn1- and sn3- FA positions of the glycerol backbone leaving a monoglycerides and 2 FA as the results of fat digestion. The 2 FA and monoacylglycerol are then incorporated into mixed lipid-bile salt micelles, with polar, aqueous parts facing outwards and the non-polar groups facing the inward core. The micelles facilitate passive diffusion into mucosal cells by making a high concentration of lipids in the unstirred water layer where the micelles make contact with microvilli. Within the enterocyte monoglycerides and FA are re-esterified, and form chylomicrons along with cholesterol, lipoprotein, and phospholipids. Chylomicrons are secreted into the lymph system but are quickly secreted into portal circulation for delivery to target tissues (Krogdahl, 1985; Ravindran et al., 2016).

Lipase is the primary lipid digester but bile salts and co-lipase must be present for lipase activity. Presence of fat in the duodenum stimulates secretion of cholecystokinin which regulates secretion of pancreatic juice and the release of bile from the gall bladder (Krogdahl, 1985; Ravindran et al., 2016). The jejunum is the major site of lipid digestion and absorption in poultry because bile duct is in distal duodenum loop (Hurwitz et al., 1973). Digestion continues in the upper ileum (Tancharoenrat et al., 2014) and absorption of fat is negligible in large intestine (Renner, 1965).

Types and Benefits of Fats:

There are many choices of fats and oils for feed manufacturing including restaurant greases, primarily yellow grease; rendered by-products, such as lard, tallow, mutton fat and poultry fat; vegetable oils such as soybean oil, corn oil, and palm oil; and acidulated soapstocks, the by-products of vegetable oil refining (Firman, 2006; Ravindran et al., 2016). Choice of fat for use in diet formulation is primarily driven by cost (Firman et al., 2008; Ravindran et al., 2016).

Fat also has advantages of reduced dustiness, lower particle separation in mash diets, improved palatability, carrier for fat soluble vitamins, supply of essential FA, lubrication of feed milling equipment, and a concentrated source of energy for increasing energy content of diets (Firman, 2006; Firman et al., 2008; Tancharoenrat et al., 2013; Ravindran et al., 2016). Fat has also been reported to slow the rate of feed passage through the digestive tract (Mateos et al., 1982) possibly allowing for increased nutrient utilization of other ingredients (Firman and Remus, 1994; Firman, 2006).

Despite many advantages of dietary fat usage, there are of course disadvantages as well. High levels of fat may negate effects of pelleting (McKinney and Teeter, 2004). The measurement of ME can be difficult and there is potential for rancidity (Firman et al., 2008) although rancidity is rarely a problem as the addition of an antioxidant is commonly used to deal with the issue and FFA below 20% is considered non-problematic (Firman, 2006). Another pitfall is the natural variation of rendered products like yellow grease as they are a mixture of fats and oils from multiple sources. This can cause variation in results between experiments and in actual production (Jiménez-Moreno et al., 2009).

Differences in Fat Sources:

Most investigators agree that digestion of fat and FA differ depending on the source of fat (Tancharoenrat et al., 2014) although not all studies indicate a difference in performance when using different fat sources (Fuller and Rendon, 1977; Fuller and Rendon, 1979; Sell et al., 1986; Ouart et al., 1992; Firman et al., 2008). Variability in energy from fat is due to many points along digestion and absorption where differences in degree of saturation, FA chain length, and position of FA can impact the extent to which they are digested and absorbed. ‘Unsaturated’ fats contain one or more double bonds while ‘saturated’ fats contain no double bonds (Ravindran et al., 2016).

Digestibility of unsaturated FA has routinely been proven better than saturated FA (Renner and Hill, 1961; Renner, 1965; Leeson and Atteh, 1995; Tancharoenrat et al., 2014). Because unsaturated FA are natural emulsifiers, they assist in mixed micelle formation and absorption. This attribute of unsaturated FA improves the digestibility of itself as well as saturated FA. Observations suggest improved digestion of saturated FA through mixing of fat source blends to increase the U:S ratio (Mateos and Sell, 1980; Tancharoenrat et al., 2014). Blending of animal fats and plant oils results in AME and fat digestibility estimates higher than the arithmetic averages of the separate ingredients (Tancharoenrat et al., 2013).

Utilization of saturated FA has also been shown to decrease as chain length increased (Renner and Hill, 1961; Tancharoenrat et al., 2014). Source of fat influenced both AME and CTTAD as expected due to U:S levels and types of FA (Tancharoenrat et al., 2013). Similarly, Tancharoenrat and coworkers (2012) found better FCR, fat retention, and ileal fat digestibility, but not improved AME with soybean oil (unsaturated) compared to tallow (saturated) in broilers 1-21 DOA.

As mentioned above, rancidity can also impact a fat’s value. Wu and coworkers (2011) found increasing levels of FFA, 2.74, 12.59, & 19.05% to reduce feed intake and growth in the grower phase while no effect was seen in the starter phase. Although this study revealed the importance of adding an antioxidant, high FFA content is not a problem since antioxidants are commonly added to fats (Firman, 2006).

Although differences in digestion and absorption of fat sources is consistently proven, these differences may not be relevant in a practical sense. As Firman and coworkers (2008) suggests, utilization of other dietary components may be equally enhanced by all fat sources regardless of ME content or U:S. Firman and coworkers (2008) also points out differences in ME of total ration, using 2 different fat sources, may be so minor that they can not be detected in research. Two fats with 7,000 and 8,000 kcal/kg ME added at 3% of the diet would only be 30 kcal/kg different in total ME, less than a 1% change in total ME. This suggests fat source does not make a significant contribution to determining performance and selection of fats based on price is best (Firman et al., 2008).

Fats Influence on Performance Parameters:

Preference has been shown for high fat diets over low fat diets in both temperate and heat stress environments for both chickens (Dale and Fuller, 1978, 1979) and turkeys (Sell and Owings, 1981). Growth and FCR were improved with high levels of fat in temperate and heat stress environments (Dale and Fuller, 1980b; McNaughton and Reece, 1984b) and improved growth was even more marked when temperatures were cycled (Dale and Fuller, 1980b). The authors suggest this partial compensation of growth depression from heat stress is due to the reduced heat increment associated with dietary fat (Dale and Fuller, 1979, 1980b).

Reduced heat increment may be a part of the phenomena termed extra caloric effects in which utilization of ME from other ingredients is improved by the addition of fat (Jensen et al., 1970; Horani and Sell, 1977; Mateos and Sell, 1980, 1981; Firman and

Remus, 1994; Tancharoenrat et al., 2013). This phenomena is found when better FCR is achieved than was expected by the quantity of ME added from the fat and may explain why some ME values reported are greater than the gross energy values possible for fat (Firman, 2006). Brue and Latshaw (1985) suggest failure to regulate caloric intake when fats are added may be a component of the extra caloric effects. Owen and coworkers (1981) refute this as he found birds maintain caloric efficiency and instead suggests differences in feed formulation may cause the differences in extra caloric effects. Mateos and Sell (1980) and Firman and Remus (1994) suggest extra caloric effect may be due to synergism of saturated and unsaturated fats to improve absorbability and a slowed rate of passage that improves digestibility of all nutrients. The extra caloric effect is likely caused by the synergism of fats with other nutrients and the slowed passage rate, but this affect may also be influenced by the many factors discussed above such as fat source, inclusion level, age of bird, etc.

Many studies have demonstrated improved growth and FCR from increased dietary fat inclusion (Fuller and Rendon, 1977; Fuller and Rendon, 1979; Sell and Owings, 1981; Brue and Latshaw, 1985). Meanwhile other studies have found similar effects of increased dietary fat inclusion but not both improved growth and FCR. Improved growth and feed efficiency was found in turkeys up to 4% added fat and only improved FE above 4% fat inclusion (Owen et al., 1981; Sell et al., 1986). Only improved FCR was found in heavy broilers with increased fat (Dozier et al., 2006b; Dozier et al., 2007a; Dozier et al., 2007b).

Saleh and coworkers (2004a) suggested that utilization of energy in diets with high levels of fat decreased at older ages in contrast to findings of Renner and Hill (1961) and Carew and coworkers (1972). Saleh and coworkers (2004a) may have interpreted their data incorrectly though. The decrease in utilization observed is likely because of the decrease in utilization of energy as fat inclusion increases, but they were unable to significantly detect the differences in ME utilization until 63 days of age because of the overall minor ME differences (Firman et al., 2008).

To find TME, fat must be assayed along with a basal diet. We know that there are fat-ingredient interactions (Tancharoenrat et al., 2012) as well as the level of fat inclusion (Plavnik et al., 1997; Sklan, 2001) affects fat digestibility thus making ME of a fat variable and difficult to assign a specific ME value to (Firman and Remus, 1994; Ravindran et al., 2016). Although Tancharoenrat et al. (2013) found there was no major strain effects on AME of multiple fats, older data on AME of fats can be questioned because of the major genetic advances of poultry. For these reasons, as Dozier et al. (2007b) suggests, ME values should be based on company history and temperature set points.

SPRAY DRIED PLASMA PROTEIN

The addition of spray dried plasma protein (SDPP) is another possible ingredient addition for use in early intervention strategies. Although animals technically only need their minimum requirements for amino acids and other nutrients (NRC, 1994), the addition of highly concentrated, digestible protein may aid in the growth of young chicks and should be seen as an investment rather than a cost (Lilburn, 1998; Ebling et al., 2015). In the case of SDPP though, there is likely an extra-nutritive effect having an impact on the immune system (Campbell et al., 2004).

The swine industry commonly uses SDPP as a protein source for early weaned pigs starter diets due to improved intake and reduced growth lag post-weaning (Bregendahl et al., 2005b; Pierce et al., 2005). This effect is likely because of biologically active factors such as enzymes, growth factors, and immunoglobulins that add value to SDPP beyond just its nutritional value. It is suggested that these factors in SDPP may reduce over-stimulation of the immune system thus using nutrients for growth and maintenance instead of immune response and improving efficiency of the animal (Pérez-Bosque et al., 2004). It is thought that a similar response could be found in poultry. It has now been well established that response to SDPP is greater in environments with a heavier pathogen load when SDPP is administered by both feed and water for pigs, broilers, and turkeys (Campbell et al., 2003; Campbell et al., 2004; Bregendahl et al., 2005a; Bregendahl et al., 2005b; Pierce et al., 2005; Campbell et al., 2006; Tran et al., 2014).

Performance parameters were unaffected in low-antigen environments, but in high-antigen environments dietary bovine SDPP improved performance when fed throughout the life of the bird (Bregendahl et al., 2005a; Bregendahl et al., 2005b). As with most studies, the researchers achieved differences in environment antigen load by reusing litter and promoting pathogen growth between flocks. Similarly, in an environment where the control group neared 55% mortality at 35 DOA and cultured positive for Escherichia coli and Salmonella, dietary SDPP improved ADG, ADFI, and FCR at 0-14 DOA and 0-35 DOA as well as improved BW and livability at 35 DOA (Campbell et al., 2006). Campbell and coworkers (2006) found the improved livability and growth parameters were seen in broilers fed SDPP continuously and broilers fed

SDPP only to 14 DOA. Alternatively, Henn and coworkers (2013) saw only minor, insignificant improvements in broilers at 42 DOA fed SDPP to 7 DOA. The difference in response is presumably due to a much weaker immune challenge in Henn and coworkers (2013) experiment.

Campbell and coworkers (2006) and Pérez-Bosque and coworkers (2004) concluded that SDPP prevents overstimulation of the immune system by providing passive protection. This in turn improves growth and FCR by subjecting less nutrients and energy to the immune system, making the body more efficient. Although their study was conducted in rats and did not measure growth, Pérez-Bosque and coworkers (2004) found SDPP and immunoglobulin concentrates (IC) reduced the percentage of several lymphocyte populations with inflammatory functions. Pérez-Bosque and coworkers (2004) also discovered that while both SDPP and IC limited immune activation, SDPP did so to a greater extent suggesting that components of SDPP besides immunoglobulins also offer positive effects. Alternatively SDPP and IC were shown to equally stimulate growth parameters in pigs (Pierce et al., 2005).

CHAPTER 3

EFFECTS OF HIGH FAT BROILER PRE-STARTER RATIONS ON PERFORMANCE AND COST

ABSTRACT

A 49 day experiment was conducted to test the addition of 6% or 8% yellow grease (YG) to diets of broilers during the 0-10 day or 0-14 day pre-starter period. Forty-eight pens of birds were fed one of 6 treatments to consist of a control (least cost addition of YG), 6% YG, or 8% YG, each fed to either 10 or 14 days. Eight replicate pens were used for each treatment arranged in a randomized complete block design with location as the blocking factor. Each pen contained 33 commercial strain broilers placed at hatch and raised to seven weeks of age. Diets consisted of commercial type corn-soy-DDGS-meat meal base and were adjusted to maintain a consistent relationship between energy and crude protein as well as amino acids. Birds were weighed and diets changed at 10 or 14 days, 17 days, or 35 days with completion of the trial at 49 days. Feed conversion was significantly improved by the addition of fat during the treatment period, a result of numerically higher body weight and reduced feed intake although neither was significant. Improved growth performance from the addition of fat during the treatment period did not result in improved performance at market, as no effects by dietary treatment were found at 49 days. Feeding a high plain of nutrition pre-starter ration to 14 days did improve feed conversion at 14 days. This effect was carried through to 49 days and similar body weights were observed. These results suggest the addition of high levels of fat in the pre-starter ration does not improve growth performance at 49 days.

INTRODUCTION

The first 2 weeks of life make up 28% of a typical broiler's life, slaughtered at 49 days, but only accounts for about 8.5% of total feed consumption (Cobb-Vantress, 2015). Lilburn (1998) and Ebling and coworkers (2015) agree that this separation gives nutritionists an opportunity to use more expensive ingredients to provide a higher plain of nutrition could improve performance during the first two weeks and should be seen as an investment rather than a cost. At current prices of about $220/ton and $200/ton in the pre-starter and finisher rations respectively, an 8% increase in the price of the pre-starter ration would have to occur to raise the total cost of feed/bird one cent (CME, 2015; Cobb-Vantress, 2015). This calculation would be assuming the increase in diet cost caused no improvements in feed efficiency and thus demonstrates the potential for cheaply improving the growth and efficiency of broilers.

Feed costs represent about 70% of the cost of poultry production (Willems et al., 2013). As the cost of feed continues to increase, improved feed conversion and reduced mortality become more valuable (Jiang et al., 1998; Donohue and Cunningham, 2009; Wood, 2009; Willems et al., 2013). For a broiler marketed at 49 days, about 50% of feed consumption occurs in the last two weeks resulting in about 50% of feed costs being incurred during this period (Cobb-Vantress, 2015). As the broiler grows older and larger, maintenance requirements increase causing a decline in feed conversion and increased feed consumption. This high amount of feed consumption later in life causes improved feed conversion to be very important economically and mortality to be expensive since the bird has already consumed so much feed. Optimizing nutrition during the first two weeks, with a practical disregard for cost, could improve gut health and insure birds develop to their maximum genetic potential. Ferket (2015) suggests under nutrition in the perinatal and immediate post-hatch nutrition are constraining development to support subsequent growth. With proper development and gut health during the immediate post-hatch period, when intense changes are occurring in the small intestine (Sklan, 2001), we may be able to improve feed conversion and reduce mortality later in the life of the bird as well as improve the final body weight (BW) of the bird at marketing.

Increased nutrient density via the use of high fat rations is a promising method for achieving optimal nutrition in the young chick. Traditionally, the young chicks ability to digest and absorb fats has been considered to be low (Renner and Hill, 1961; Carew et al., 1972; Krogdahl, 1985; Sell et al., 1986; Tancharoenrat et al., 2013). These studies have caused a dogma in poultry nutrition that fats should not be used in the diets of young chicks, but this is no reason to avoid fats since the young chick is outfitted for fatty acid metabolism (Lilburn, 1998), digestion improves rapidly (Firman, 2006), and total absorption of fat and energy increases with increased dietary fat inclusion (Noy and Sklan, 2001). Fat, starch, and amino acid digestibility are all lowest in the young chick during the first week and all improve with age (Noy and Sklan, 1995; Batal and Parsons, 2002; Thomas et al., 2008). The young chick also has a low capacity for feed consumption due to physical limitations. Utilization of a high nutrient density diets via the use of high dietary fat inclusion thus has the potential to increase total nutrient uptake in the young chick.

The primary objective of this experiment was to determine if high fat pre-starter rations could improve initial performance of chicks and if the observed increase would be maintained to market weight.

MATERIALS AND METHODS

General Procedures

To determine if industry growth standards could be improved, an experiment was conducted using as hatched Cobb/Cobb birds obtained from a commercial hatchery. Birds were housed and maintained according to the University of Missouri standard operating procedures and the University of Missouri Animal Care and Use Guidelines. Standard US corn-soy-DDGS-animal byproduct diets were used with the exception of the changes in yellow grease addition.

Trial Design

Forty-eight pens of broilers with 33 birds/pen for a total of 1,584 birds were used in a 2 x 3 factorial design with 6 treatments and 8 replicate pens. Treatments included a low fat pre-starter diet, 6% or 8% added fat (yellow grease) x 10 days and 14 days on diet. These diets were fed for either the 10 or 14 day period followed by industry standard diets through the remaining growout period with ration changes at 17 and 35 days. Each floor pen measured 4 feet wide and 8 feet deep, and contained one metal feeder, one nipple waterer with 5 nipples each 6 inches apart, one heat lamp, and new cedar shavings. Supplemental feed trays were used in each pen from 0 to 5 days to encourage acclimation to feed. Heat lamps were used during brood and removed at 14 days of age. Birds received continuous light throughout the trial.

Treatment Descriptions

Three experimental diets were fed representing 6 treatments with time fed being the other variable. Experimental diets consisted of an industry standard control diet (C), 6% added fat (YG6), or 8% added fat (YG8) (Table 3.1). Fat used was yellow grease

(YG) (15% max FFA) from Hahn and Phillips Grease Company in Marshall, MO. The control diet and post-experimental period diets (Table 3.2) were industry standard diets based on Cobb-Vantress (2015) recommendations, formulated on a digestible amino acids basis and a minimum level of CP. Minimum constraints were placed on YG to force 6 or 8% fat addition. Energy was allowed to increase accordingly. Crude protein (CP) and amino acids (AA) were increased to maintain a consistent CP and AA ratio to energy across all treatments. Fat addition and adjustment for CP and AA were done without regard to cost. All diets were formulated using least-cost formulation software, and included an industry provided premix.

Measurements

Birds were weighed by pen at 0, 10, 14, 17, 35, and 49 days via electronic scale. Feed was weighed and placed in front of pens; a total quantity was recorded at that time and feed disappearance measured at 10 or 14, 17, 35, and 49 days. Mortality weights were recorded daily and used to adjust feed conversion. Feed intake, body weight gain, feed conversion, and adjusted feed conversion were calculated for each period. At 49 days of age, 3 birds per pen (24 birds per treatment), of average weight for their pen, were selected for processing. On day 50 birds were processed to determine carcass and parts yield. Parts collected were pectoralis major and minor, thigh, leg, wing, and fat pad.

Statistical Analysis:

The experiment was a complete randomized block design with the position of each block of pens in the barn being the blocking factor. Data was analyzed by analysis of variance (ANOVA) with a two-way design with the pen being the experimental unit throughout the study. All statements are based on the 0.05 level of significance. Mean separations were done as appropriate using the Tukey's least significant difference test.

RESULTS

Body weight was similar across treatments at 10 DOA, although feed intake (FI) of treatment Cx10 was significantly higher than all other treatments except Cx14 at 10 DOA (Table 3.3). From 0 to 10 days birds fed diet C did not consume significantly more than diets YG6 or YG8 (p-value=0.128, not shown) but feed/gain and adjusted feed/gain were both significantly poorer in birds fed diet C than diets YG6 or YG8 (Table 3.3).

At 14 days, YG8x10 was significantly heavier than all other treatments except Cx10 while Cx14 was significantly lighter than all other treatments except YG6x14 (Table 3.4). From 10 to 14 days, birds fed a pre-starter ration to 10 DOA consumed and gained significantly more than birds fed a pre-starter ration to 14 DOA resulting in significantly poorer feed conversion of birds fed pre-starter to 10 days during the 10 to 14 day period (Table 3.8). Consequently, birds fed pre-starter to 10 days were found to have significantly increased cumulative BW, feed intake, and feed/gain (Table 3.4). Cumulative feed consumption at 14 DOA was significantly higher in birds fed diet C than YG6 but not significantly greater than YG8 (Table 3.4). This resulted in significantly improved feed conversion as fat inclusion increased (Table 3.4). Interactive effects were found in treatments cumulative feed/gain and adjusted feed/gain at 14 DOA (Table 3.4) although only YG8x14 was significantly lower than all other treatments during the 10 to 14 day period (Table 3.8).

From 14 to 17 days, birds fed a pre-starter ration to 14 days gained significantly more weight than birds fed a pre-starter ration to 10 DOA despite similar feed intake causing significantly poorer feed conversion in birds fed pre-starter to 10 DOA (Table 3.9). Cumulative feed intake at 17 DOA was significantly increased in birds fed pre-starter to 10 days due to the difference found at 14 DOA resulting in significantly poorer feed conversion of birds fed pre-starter to 10 days (Table 3.5). Cumulative feed intake and BW at 17 DOA was similar when comparing diet or time fed pre-starter separately although feed conversion was significantly higher in birds fed diet C than YG6 or YG8 (Table 3.5).

There were no cumulative or period effects from time fed pre-starter or diet on BW or feed intake after 17 DOA (Tables 3.6, 3.7, 3.10, 3.11) although cumulative feed consumption of YG8x10 was significantly higher than YG6x14 at both 35 (Table 3.6) and 49 DOA (Table 3.7). At 49 DOA feed conversion of treatment Cx10 was significantly poorer than treatments Cx14, YG6x10, and YG8x14 (Table 3.7). Cumulative feed conversion at 49 DOA was also found to be significantly poorer (2.25 points) in birds fed pre-starter to 10 days than 14 days (Table 3.7).

Although no significance was found between treatments at 49 DOA, treatment C was heaviest followed by YG6 or YG8, each about 40 grams lighter than the previous (Table 3.7). Final BW at 49 DOA was heavier than expected at an average of 3.60 kg, 0.10 kg above the suggested 49 day BW of 3.50 kg (Cobb-Vantress, 2015).

Under normal conditions with no extreme immune challenge, livability was unaffected throughout the trial.

At 50 days of age, three birds of average weight from each pen were slaughtered and parts yield measured. All treatments were similar in percentage of hot carcass, fat pad, major, minor, and total breast, leg, thigh, and wing (Table 3.12). Comparison of diet and time on pre-starter diet were also similar.

DISCUSSION

The primary objective of this study was to determine if high fat pre-starter rations could improve initial performance of chicks and if the observed increase in performance would be maintained to market weight. To do so, birds were fed a pre-starter ration of either a standard low fat diet (C), 6% added fat (YG6), or 8% added fat (YG8) (Table 3.1) for either 10 or 14 days. Yellow grease (YG) was used in this study as it is typically the cheapest source of fat and cost is the recommended selection determinate (Firman et al., 2008).

Consistent with previous research (Fuller and Rendon, 1979; Sell and Owings, 1981; Brue and Latshaw, 1985; Saleh et al., 2004a, b; Dozier et al., 2011; Tancharoenrat and Ravindran, 2014), feed conversion was significantly improved by the addition of fat during the treatment period at 10 and 14 DOA as well as immediately following the treatment period at 17 DOA (Tables 3.3, 3.4, 3.5). This effect was primarily caused by reduced feed intake in birds consuming additional fat as BW was similar across dietary treatments. BW, cumulative feed intake, and cumulative feed conversion were all similar across dietary treatments after 17 DOA (Table 3.6, 3.7).

Lilburn (1998) and Ebling and coworkers (2015) have suggested feeding a higher plain of nutrition during the first 2 weeks of life may better meet the needs of the broiler and improve performance at marketing. This theory is not supported by the present study conducted with broilers in a standard floor pen trial. Fat, starch, and amino acid digestibility are all lowest in the young chick during the first week (Noy and Sklan, 1995;

Batal and Parsons, 2002). Inclusion of a high level of fat, and thus a high plain of nutrition did improve total nutrient retention as feed conversion was improved at 10, 14, and 17 DOA but this effect was not apparent at market (Table 3.7). This improved feed conversion also suggests the use of fats in the diets of young chicks is advisable in agreement with Lilburn (1998).

Although BW was similar between dietary treatments at 10 and 14 DOA (Table 3.5), weight gain was significantly higher and feed conversion was significantly improved in birds consuming YG8 from 10 to 14 days (Table 3.8). In addition, weight gain and feed intake were both significantly higher in birds fed pre-starter to 10 DOA (Table 3.8). In Table 3.8, weight gain is significantly higher in birds fed pre-starter to 10 DOA and YG8x14 over Cx14 and YG6x14. This would appear to confirm the suggestions set by Cobb-Vantress (2015) that a feed change should occur at 10 DOA as the bird appears to require a higher level of energy post 10 DOA. This may not be the case though as treatment YG8x14 feed conversion was significantly better at 14 DOA than all other treatments (Tables 3.4, 3.8) suggesting the bird may still require a high level of energy and protein to 14 DOA. In addition, weight gain and feed conversion were significantly improved from 14 to 17 days in broilers fed pre-starter to 14 DOA compared to pre-starter to 10 DOA (Table 3.9). Consequently, at 17 DOA broilers fed pre-starter to 14 DOA had numerically heavier BW, significantly reduced cumulative feed intake, and significantly improved cumulative feed conversion (Table 3.5). Although no significant cumulative effects were found at 35 DOA, feed conversion was significantly improved in broilers fed pre-starter to 14 DOA compared to broilers fed pre-starter to 10 DOA (Table 3.7).

From the present study, we find the broiler gains more weight immediately following a feed change but improvement in feed conversion does not mirror the improvement in weight gain (Tables 3.8, 3.9). Feeding pre-starter to 14 DOA rather than 10 DOA appears to be beneficial as cumulative feed conversion was significantly improved at 49 DOA (Table 3.7). Feeding a pre-starter ration for a longer period would likely be more beneficial to growth but cost must be considered as a pre-starter ration is essentially a diet with a higher plain of nutrition and thus costs more.

Broilers are commonly fed a starter ration to 17 or 21 days (NRC, 1994). According to the present study, feeding a pre-starter ration with a high plain of nutrition via the addition of high levels of fat to 14 DOA may improve cumulative feed conversion at market thus reducing cost of gain. Maximizing the improvement in feed conversion will require further research to determine at what age a pre-starter, high plain of nutrition ration should be fed to while reduced cost of gain will be highly dependent on ingredient cost and the level of nutrient inclusion in the pre-starter ration.

Today's broiler appears to have an outstanding ability to compensate for lack of BW gain and achieve flock uniformity. This is likely due to the remarkable improvements in broiler genetics (Havenstein et al., 2003b, a) leading to a drive in the broiler to maximally consume feed and grow accordingly. In the current study, Cx14 was the lightest treatment at 17 DOA (Table 3.5) but was the heaviest at both 35 (Table 3.6) and 49 DOA (Table 3.7). At 49 DOA, BW was similar across all treatments with only 130 gram (3.6% of average 49 day BW) difference between the lightest and heaviest treatment (Table 3.7). Studies in how today's broiler adjusts and compensates to deficient or excess energy and protein may lead to a better understanding of how to improve growth through marketing or how to more cheaply feed the birds with early intervention strategies.

CONCLUSION

Additional fat in the pre-starter diet did not result in improved BW or improved feed conversion at market. Feeding the pre-starter ration to 14 DOA rather than 10 DOA did result in improved feed conversion at 49 DOA but further research should be conducted to determine the ideal plain of nutrition and time feeding the pre-starter ration. Under normal conditions, the addition of high level of fats during the pre-starter phase only is not recommended. In the current study, significant improvements in growth and feed conversion were not observed at market and inclusion of high levels of fat raised the pre-starter diet cost.

Table 3.1. Ingredient composition and nutrient profile of experimental diets fed to broilers to either 10 or 14 days of age.

	Treatments		
	C	YG6	YG8
Ingredient	%	%	%
Corn	59.28	50.27	46.41
Soybean Meal	27.01	31.17	32.94
Porkmeal	5.00	5.00	5.00
Corn DDGS	5.00	5.00	5.00
Yellow Grease[1]	1.33	6.00	8.00
Dicalcium Phosphate	0.59	0.72	0.77
Copper Sulfate	0.00	0.00	0.00
Sodium Chloride	0.32	0.32	0.32
Limestone	0.51	0.55	0.60
Choline Chloride	0.02	0.01	0.00
Vitamin/Mineral Premix[2,3]	0.18	0.18	0.18
DL-Methionine	0.33	0.36	0.37
Lysine HCL	0.26	0.23	0.22
Threonine	0.15	0.15	0.15
Avatec	0.05	0.05	0.05
Nutrient			
ME (kcal/kg)	3035	3209	3283
Crude Protein	22.00	23.30	23.85
Calcium	0.90	0.95	0.98
Available Phosphorus	0.45	0.48	0.49
Lysine	1.18	1.25	1.28
Methionine + Cysteine	0.88	0.93	0.95
Threonine	0.77	0.82	0.84
Valine	0.80	0.85	0.87

[1] Yellow Grease Analysis: Total fatty acids, min. 90.0%; Moisture, max. 1.0%; Insoluble impurities, max. 0.5%; Unsaponifiable matter, max. 1.0%; Total M.I.U., max. 2.0%; Free fatty acids, max. 15.0%.

[2] Vitamins provided per kilogram: Vitamin E 93,697 mg; B-12 18000 mcg; Thiamin 2,343 mg; Riboflavin 9,369 mg; Niacin 81,983 mg; Pyridoxine 5,857 mg; Biotin 205 mg; Folate 3,514 mg

[3] Minerals provided per kilogram: Mn 160,000 mg; Zn 150,000 mg; Fe 10,000 mg; Se 240 mg; Mg 20,000 mg

Table 3.2. Ingredient composition and nutrient profile of common diets fed to broilers in all treatments starting at either 11 or 15 days of age through 49 days of age.

	Period		
	11-17	18-35	36-49
Ingredient	%	%	%
Corn	63.79	65.46	67.95
Soybean Meal	22.22	20.06	17.60
Porkmeal	5.00	5.00	5.00
Corn DDGS	5.00	5.00	5.00
Yellow Grease[1]	1.88	2.77	2.74
Dicalcium Phosphate	0.48	0.31	0.32
Copper Sulfate	0.00	0.00	0.00
Sodium Chloride	0.32	0.32	0.32
Limestone	0.44	0.33	0.34
Choline Chloride	0.00	0.00	0.00
Vitamin/Mineral Premix[2,3]	0.18	0.18	0.18
DL-Methionine	0.28	0.24	0.22
Lysine HCL	0.24	0.18	0.20
Threonine	0.13	0.11	0.10
Avatec	0.05	0.05	0.05
Nutrient			
ME (kcal/kg)	3110	3180	3200
Crude Protein	20	19	18
Calcium	0.84	0.76	0.76
Available Phosphorus	0.42	0.38	0.38
Lysine	1.05	0.95	0.90
Methionine + Cysteine	0.80	0.74	0.70
Threonine	0.69	0.65	0.61
Valine	0.73	0.70	0.66

[1] Yellow Grease Analysis: Total fatty acids, min. 90.0%; Moisture, max. 1.0%; Insoluble impurities, max. 0.5%; Unsaponifiable matter, max. 1.0%; Total M.I.U., max. 2.0%; Free fatty acids, max. 15.0%.

[2] Vitamins provided per kilogram: Vitamin E 93,697 mg; B-12 18000 mcg; Thiamin 2,343 mg; Riboflavin 9,369 mg; Niacin 81,983 mg; Pyridoxine 5,857 mg; Biotin 205 mg; Folate 3,514 mg

[3] Minerals provided per kilogram: Mn 160,000 mg; Zn 150,000 mg; Fe 10,000 mg; Se 240 mg; Mg 20,000 mg

Table 3.3. Growth performance from 0 to 10 days of broilers fed control (C), 6% addition of YG (YG6), or 8% addition of YG (YG8) for either 10 days (x10) or 14 days (x14).

Treatment	Livability (%)	Body Weight (kg)	Feed Intake (kg)	Feed/Gain	Adjusted Feed/Gain
Cx10[1]	0.975	0.269	0.258^{a}	1.115^{a}	1.105^{a}
Cx14[1]	0.960	0.264	0.238^{ab}	1.114^{a}	1.099^{a}
YG6x10[1]	0.977	0.269	0.227^{b}	1.026^{b}	1.029^{b}
YG6x14[1]	0.981	0.269	0.230^{b}	1.025^{b}	1.018^{b}
YG8x10[1]	0.970	0.275	0.233^{b}	1.011^{b}	1.014^{b}
YG8x14[1]	0.978	0.270	0.229^{b}	1.010^{b}	1.011^{b}
Diet					
C[2]	0.958	0.259	0.240	1.114^{a}	1.120^{a}
YG6[2]	0.979	0.266	0.229	1.025^{b}	1.020^{b}
YG8[2]	0.964	0.266	0.225	1.026^{b}	1.009^{b}
Time					
10 days[3]	0.974	0.264	0.232	1.055	1.047
14 days[3]	0.960	0.264	0.230	1.055	1.046
Pooled SE	0.028	0.014	0.013	0.024	0.018

[a-b] Means within a column with no common superscripts differ significantly by Tukey method ($p<0.05$).

[1] Data are means of eight replicate pens initially containing 33 broilers per pen.

[2] Data are means of 16 replicate pens initially containing 33 broilers per pen.

[3] Data are means of 24 replicate pens initially containing 33 broilers per pen.

Table 3.4. Cumulative growth performance from 0 to 14 days of broilers fed control (C), 6% addition of YG (YG6), or 8% addition of YG (YG8) for either 10 days (x10) or 14 days (x14).

Treatment	Livability (%)	Body Weight (kg)	Feed Intake (kg)	Feed/Gain	Adjusted Feed/Gain
Cx10[1]	0.988	0.467^{ab}	0.529^{a}	1.267^{a}	1.233^{a}
Cx14[1]	0.976	0.424^{d}	0.452^{c}	1.224^{ab}	1.197^{b}
YG6x10[1]	0.970	0.449^{bc}	0.492^{b}	1.214^{b}	1.201^{b}
YG6x14[1]	0.981	0.438^{cd}	0.438^{c}	1.140^{c}	1.138^{c}
YG8x10[1]	0.970	0.474^{a}	0.513^{ab}	1.200^{b}	1.189^{b}
YG8x14[1]	0.974	0.448^{bc}	0.442^{c}	1.103^{c}	1.093^{d}
Diet					
C[2]	0.959	0.441	0.494^{a}	$1.245^{a, 4}$	$1.223^{a, 4}$
YG6[2]	0.975	0.447	0.472^{b}	$1.151^{b, 4}$	$1.170^{b, 4}$
YG8[2]	0.972	0.456	0.477^{ab}	$1.177^{b, 4}$	$1.141^{c, 4}$
Time					
10 days[3]	0.970	0.460^{a}	0.513^{a}	$1.227^{a, 4}$	$1.211^{a, 4}$
14 days[3]	0.968	0.436^{b}	0.448^{b}	$1.156^{b, 4}$	$1.145^{b, 4}$
Pooled SE	0.033	0.015	0.021	0.031	0.019

[a-d] Means within a column with no common superscripts differ significantly by Tukey method ($p<0.05$).

[1] Data are means of eight replicate pens initially containing 33 broilers per pen.

[2] Data are means of 16 replicate pens initially containing 33 broilers per pen.

[3] Data are means of 24 replicate pens initially containing 33 broilers per pen.

[4] Interaction within the column was also significant ($p<0.05$).

Table 3.5. Cumulative growth performance from 0 to 17 days of broilers fed control (C), 6% addition of YG (YG6), or 8% addition of YG (YG8) for either 10 days (x10) or 14 days (x14).

Treatment	Livability (%)	Body Weight (kg)	Feed Intake (kg)	Feed/Gain	Adjusted Feed/Gain
Cx10[1]	0.939	0.618^{ab}	0.770^{a}	1.319^{a}	1.278^{a}
Cx14[1]	0.934	0.591^{b}	0.696^{bc}	1.290^{a}	1.226^{bc}
YG6x10[1]	0.939	0.603^{ab}	0.738^{abc}	1.293^{a}	1.254^{ab}
YG6x14[1]	0.947	0.610^{ab}	0.689^{bc}	1.224^{b}	1.193^{cd}
YG8x10[1]	0.935	0.625^{a}	0.741^{ab}	1.288^{a}	1.241^{ab}
YG8x14[1]	0.944	0.604^{ab}	0.682^{c}	1.179^{b}	1.156^{d}
Diet					
C[2]	0.937	0.604	0.725	1.310^{a}	1.258^{a}
YG6[2]	0.947	0.611	0.720	1.250^{b}	1.218^{b}
YG8[2]	0.939	0.622	0.712	1.242^{b}	1.200^{b}
Time					
10 days[3]	0.938	0.606	0.749^{a}	1.304^{a}	1.258^{a}
14 days[3]	0.945	0.618	0.689^{b}	1.231^{b}	1.192^{b}
Pooled SE	0.034	0.021	0.037	0.034	0.026

$^{a-d}$ Means within a column with no common superscripts differ significantly by Tukey method ($p<0.05$).

[1] Data are means of eight replicate pens initially containing 33 broilers per pen.

[2] Data are means of 16 replicate pens initially containing 33 broilers per pen.

[3] Data are means of 24 replicate pens initially containing 33 broilers per pen.

Table 3.6. Cumulative growth performance from 0 to 35 days of broilers fed control (C), 6% addition of YG (YG6), or 8% addition of YG (YG8) for either 10 days (x10) or 14 days (x14).

Treatment	Livability (%)	Body Weight (kg)	Feed Intake (kg)	Feed/Gain	Adjusted Feed/Gain
Cx10[1]	0.952	2.169^{ab}	3.253^{ab}	1.509	1.493
Cx14[1]	0.939	2.216^{a}	3.248^{ab}	1.490	1.477
YG6x10[1]	0.924	2.151^{ab}	3.218^{ab}	1.512	1.486
YG6x14[1]	0.943	2.098^{b}	3.143^{b}	1.501	1.491
YG8x10[1]	0.926	2.175^{ab}	3.271^{a}	1.507	1.493
YG8x14[1]	0.935	2.127^{ab}	3.248^{ab}	1.486	1.476
Diet					
C[2]	0.933	2.193	3.262	1.500	1.490
YG6[2]	0.934	2.158	3.195	1.508	1.486
YG8[2]	0.931	2.179	3.221	1.514	1.491
Time					
10 days[3]	0.930	2.174	3.250	1.517	1.498
14 days[3]	0.935	2.179	3.203	1.497	1.480
Pooled SE	0.027	0.067	0.074	0.024	0.027

[a-b] Means within a column with no common superscripts differ significantly by Tukey method ($p<0.05$).

[1] Data are means of eight replicate pens initially containing 33 broilers per pen.

[2] Data are means of 16 replicate pens initially containing 33 broilers per pen.

[3] Data are means of 24 replicate pens initially containing 33 broilers per pen.

Table 3.7. Cumulative growth performance from 0 to 49 days of broilers fed control (C), 6% addition of YG (YG6), or 8% addition of YG (YG8) for either 10 days (x10) or 14 days (x14).

Treatment	Livability (%)	Body Weight (kg)	Feed Intake (kg)	Feed/Gain	Adjusted Feed/Gain
Cx10[1]	0.947	3.532	6.138^{ab}	1.757	1.730^{a}
Cx14[1]	0.933	3.661	6.101^{ab}	1.689	1.671^{b}
YG6x10[1]	0.917	3.574	6.017^{ab}	1.717	1.686^{b}
YG6x14[1]	0.928	3.612	5.938^{b}	1.690	1.691^{ab}
YG8x10[1]	0.913	3.646	6.169^{a}	1.720	1.686^{ab}
YG8x14[1]	0.913	3.610	5.953^{ab}	1.718	1.6832^{b}
Diet					
C[2]	0.935	3.645	6.120	1.722	1.698
YG6[2]	0.922	3.606	5.978	1.704	1.677
YG8[2]	0.913	3.563	6.093	1.736	1.685
Time					
10 days[3]	0.926	3.587	6.086	1.730	1.699^{a}
14 days[3]	0.921	3.623	6.041	1.711	1.674^{b}
Pooled SE	0.038	0.087	0.137	0.043	0.026

[a-b] Means within a column with no common superscripts differ significantly by Tukey method ($p<0.05$).

[1] Data are means of eight replicate pens initially containing 33 broilers per pen.

[2] Data are means of 16 replicate pens initially containing 33 broilers per pen.

[3] Data are means of 24 replicate pens initially containing 33 broilers per pen.

Table 3.8. Growth performance from 10 to 14 days of broilers fed control (C), 6% addition of YG (YG6), or 8% addition of YG (YG8) for either 10 days (x10) or 14 days (x14).

Treatment	Livability (%)	Body Weight Gain (kg)	Feed Intake (kg)	Feed/Gain	Adjusted Feed/Gain
Cx10[1]	0.988	0.196^{a}	0.278^{a}	1.392^{a}	1.373^{a}
Cx14[1]	0.976	0.161^{b}	0.221^{b}	1.335^{a}	1.332^{a}
YG6x10[1]	0.970	0.194^{a}	0.267^{a}	1.411^{a}	1.398^{a}
YG6x14[1]	0.981	0.157^{b}	0.209^{b}	1.333^{a}	1.333^{a}
YG8x10[1]	0.970	0.198^{a}	0.280^{a}	1.402^{a}	1.400^{a}
YG8x14[1]	0.974	0.183^{a}	0.216^{b}	1.199^{b}	1.198^{b}
Diet					
C[2]	0.959	0.179^{b}	0.247	1.366$^{a, 4}$	1.362$^{a, 4}$
YG6[2]	0.975	0.179^{b}	0.239	1.361$^{a, 4}$	1.352$^{a, 4}$
YG8[2]	0.972	0.190^{a}	0.246	1.300$^{b, 4}$	1.299$^{b, 4}$
Time					
10 days[3]	0.970	0.196^{a}	0.273^{a}	1.402$^{a, 4}$	1.394$^{a, 4}$
14 days[3]	0.968	0.169^{b}	0.215^{b}	1.282$^{b, 4}$	1.281$^{b, 4}$
Pooled SE	0.033	0.01352	0.01118	0.0517	0.0553

$^{a-b}$ Means within a column with no common superscripts differ significantly by Tukey method ($p<0.05$).

[1] Data are means of eight replicate pens initially containing 33 broilers per pen.

[2] Data are means of 16 replicate pens initially containing 33 broilers per pen.

[3] Data are means of 24 replicate pens initially containing 33 broilers per pen.

[4] Interaction within the column was also significant ($p<0.05$).

Table 3.9. Growth performance from 14 to 17 days of broilers fed control (C), 6% addition of YG (YG6), or 8% addition of YG (YG8) for either 10 days (x10) or 14 days (x14).

Treatment	Livability (%)	Body Weight Gain (kg)	Feed Intake (kg)	Feed/Gain	Adjusted Feed/Gain
Cx10[1]	0.939	0.152	0.218	1.560^{a}	1.395^{a}
Cx14[1]	0.934	0.175	0.219	1.410^{c}	1.297^{b}
YG6x10[1]	0.939	0.156	0.224	1.516^{ab}	1.373^{a}
YG6x14[1]	0.947	0.173	0.226	1.429^{bc}	1.307^{b}
YG8x10[1]	0.935	0.160	0.218	1.569^{a}	1.345^{ab}
YG8x14[1]	0.944	0.175	0.208	1.425^{bc}	1.302^{b}
Diet					
C[2]	0.937	0.163	0.219	1.500	1.349
YG6[2]	0.947	0.164	0.223	1.492	1.357
YG8[2]	0.939	0.165	0.217	1.497	1.343
Time					
10 days[3]	0.938	$.158^{b}$	0.219	1.547^{a}	1.384^{a}
14 days[3]	0.945	$.170^{a}$	0.221	1.446^{b}	1.316^{b}
Pooled SE	0.034	0.015	0.019	0.057	0.033

$^{a\text{-}c}$ Means within a column with no common superscripts differ significantly by Tukey method ($p<0.05$).

[1] Data are means of eight replicate pens initially containing 33 broilers per pen.

[2] Data are means of 16 replicate pens initially containing 33 broilers per pen.

[3] Data are means of 24 replicate pens initially containing 33 broilers per pen.

Table 3.10. Growth performance from 17 to 35 days of broilers fed control (C), 6% addition of YG (YG6), or 8% addition of YG (YG8) for either 10 days (x10) or 14 days (x14).

Treatment	Livability (%)	Body Weight Gain (kg)	Feed Intake (kg)	Feed/Gain	Adjusted Feed/Gain
Cx10[1]	0.952	1.554^{ab}	2.473	1.574	1.574
Cx14[1]	0.939	1.625^{a}	2.555	1.561	1.561
YG6x10[1]	0.924	1.584^{ab}	2.484	1.598	1.582
YG6x14[1]	0.943	1.529^{b}	2.460	1.602	1.602
YG8x10[1]	0.926	1.570^{ab}	2.499	1.589	1.601
YG8x14[1]	0.935	1.523^{b}	2.501	1.609	1.598
Diet					
C[2]	0.933	1.589	2.528	1.567^{b}	1.567
YG6[2]	0.934	1.547	2.472	1.594^{ab}	1.586
YG8[2]	0.931	1.557	2.500	1.599^{a}	1.594
Time					
10 days[3]	0.930	1.556	2.492	1.587	1.582
14 days[3]	0.935	1.572	2.508	1.587	1.583
Pooled SE	0.027	0.059	0.063	0.033	0.032

$^{a\text{-}b}$ Means within a column with no common superscripts differ significantly by Tukey method ($p<0.05$).

[1] Data are means of eight replicate pens initially containing 33 broilers per pen.

[2] Data are means of 16 replicate pens initially containing 33 broilers per pen.

[3] Data are means of 24 replicate pens initially containing 33 broilers per pen.

Table 3.11. Growth performance from 35 to 49 days of broilers fed control (C), 6% addition of YG (YG6), or 8% addition of YG (YG8) for either 10 days (x10) or 14 days (x14).

Treatment	Livability (%)	Body Weight Gain (kg)	Feed Intake (kg)	Feed/Gain	Adjusted Feed/Gain
Cx10[1]	0.947	1.431	2.914	2.107	2.095
Cx14[1]	0.933	1.438	2.848	1.997	1.974
YG6x10[1]	0.917	1.422	2.824	1.969	1.976
YG6x14[1]	0.928	1.473	2.813	1.974	1.975
YG8x10[1]	0.913	1.394	2.835	2.065	2.011
YG8x14[1]	0.913	1.376	2.870	2.022	1.980
Diet					
C[2]	0.935	1.434	2.881	2.052	1.996
YG6[2]	0.922	1.448	2.806	1.970	1.958
YG8[2]	0.913	1.385	2.823	2.104	2.011
Time					
10 days[3]	0.926	1.415	2.849	2.047	2.013
14 days[3]	0.921	1.429	2.825	2.037	1.964
Pooled SE	0.038	0.119	0.099	0.082	0.097

[a-b] Means within a column with no common superscripts differ significantly by Tukey method ($p<0.05$).

[1] Data are means of eight replicate pens initially containing 33 broilers per pen.

[2] Data are means of 16 replicate pens initially containing 33 broilers per pen.

[3] Data are means of 24 replicate pens initially containing 33 broilers per pen.

Table 3.12. Processing yields of broilers at 50 days of age, after 12 hours fasting, fed control (C), 6% addition of YG (YG6), or 8% addition of YG (YG8) for either 10 days (x10) or 14 days (x14).

Treatment	Hot Carcass[4]	Fat Pad[5]	Major Breast[5]	Minor Breast[5]	Total Breast[5]	Leg[5]	Thigh[5]	Wing[5]
Cx10[1]	71.39	2.33	26.11	5.36	31.08	15.29	18.64	11.57
Cx14[1]	72.68	2.59	26.56	5.52	31.67	15.10	19.16	11.45
YG6x10[1]	72.04	2.55	26.46	5.54	32.00	15.30	19.30	11.78
YG6x14[1]	72.40	2.50	26.09	5.51	31.68	15.22	18.81	11.23
YG8x10[1]	71.70	2.91	25.92	5.29	31.22	15.20	18.97	11.60
YG8x14[1]	72.68	2.44	26.50	5.36	31.83	15.05	18.65	11.58
Diet								
C[2]	72.41	2.46	26.09	5.31	31.37	15.30	18.99	11.56
YG6[2]	72.43	2.59	26.27	5.57	31.84	15.33	18.99	11.50
YG8[2]	72.24	2.72	26.39	5.33	31.72	15.13	18.81	11.58
Time								
10 days[3]	72.17	2.64	26.08	5.37	31.43	15.30	18.93	11.68
14 days[3]	72.56	2.54	26.42	5.44	31.86	15.21	18.93	11.41
Pooled SE	1.96	0.83	2.40	0.68	2.91	1.19	1.38	0.88

[a-b] Means within a column with no common superscripts differ significantly by Tukey method ($p<0.05$).

[1] Data are means of 24 carcasses per treatment.

[2] Data are means of 48 carcasses per treatment.

[3] Data are means of 72 carcasses per treatment.

[4] Expressed as a percent of live weight.

[5] Expressed as a percent of the hot carcass weight.

CHAPTER 4

EFFECTS OF ADDITION OF SPRAY DRIED PLASMA PROTEIN TO BROILER PRE-STARTER RATIONS

ABSTRACT

Porcine plasma protein is a byproduct of the swine rendering industry commonly used in feeding young pigs as an effective protein source. Plasma protein has been shown to have a variety of components that may enhance immune function in pigs and other species resulting in growth and feed efficiency comparable to that seen in new barns. The objective of this study was to test if the addition of porcine plasma protein would improve growth and feed efficiency in the broiler when fed during the pre-starter period. Forty eight pens of 30 Hubbard/Ross chickens were fed a control (no plasma), 0.5% added plasma, or 1% added plasma to 10 days with 16 replicates of each treatment, arranged in a randomized block design. Birds were fed corn-soy-DDGS-meat meal base diets similar in nutrient content. After the 10 day treatment period, all birds were fed the same diets until slaughter at 49 days. Birds and feed were weighed at 0, 10, 21, 35, and 49 days for growth and feed efficiency data and on day 50, three birds/pen were slaughtered for parts yield. At 10 days of age, feed:gain was significantly improved in the control treatment. After day 10 no consistent effects were observed in growth, feed efficiency, or parts yield.

INTRODUCTION

The swine industry commonly uses spray dried plasma protein (SDPP) as a protein source for starter diets in early weaned pigs due to improved intake and reduced growth lag post-weaning (Bregendahl et al., 2005b; Pierce et al., 2005). This effect is likely because of biologically active factors such as enzymes, growth factors, and immunoglobulins that add value to SDPP beyond just its nutritional value. It is suggested that these factors in SDPP may reduce over-stimulation of the immune system thus using nutrients for growth and maintenance instead of immune response thus improving efficiency of the animal (Pérez-Bosque et al., 2004). It is thought that a similar response could be found in poultry.

Although animals technically only need their minimum requirements for amino acids and other nutrients (NRC, 1994), the addition of highly concentrated, digestible protein may aid in the growth of young chicks and should be seen as an investment rather than a cost (Lilburn, 1998; Ebling et al., 2015). Amino acid (AA), carbohydrate, and fat digestibility's have all been shown to improve with age (Noy and Sklan, 1995, 1999b; Noy and Sklan, 2001; Batal and Parsons, 2002), thus the chick's capacity to digest nutrients is lowest during the first week than any other period of life. The use of highly digestible proteins while the chick is young may be very advantageous as the first two weeks of life accounts for 28% of a seven week broiler's life but only accounts for about 8.5% of total feed consumption (Cobb-Vantress, 2015). With such low feed intake during the first two weeks the increase in total cost is minimal despite the typically prohibitive cost of highly digestible proteins. Optimizing nutrition during the first two weeks, with a practical disregard for cost, could improve gut health and insure birds develop to their maximum genetic potential. Ferket (2015) suggested that under-nutrition in the perinatal and immediate post-hatch nutrition are constraining development to support subsequent growth. With proper development and gut health during the immediate post-hatch period, when intense changes are occurring in the small intestine (Sklan, 2001), we may be able to improve feed conversion and reduce mortality later in the life of the bird as well as improve the final body weight (BW) of the bird at marketing.

Spray dried plasma protein has consistently been shown to improve livability in high pathogen environments but consistent benefit has been absent in low pathogen environments for pigs, broilers, and turkeys (Campbell et al., 2003; Campbell et al., 2004; Bregendahl et al., 2005a; Bregendahl et al., 2005b; Pierce et al., 2005; Campbell et al., 2006; Tran et al., 2014). The addition of SDPP from 0 to 14 days of age (DOA) has been shown to improve livability and growth parameters at 35 DOA when exposed to an extreme pathogen load (Campbell et al., 2006). For this reason, the addition of SDPP to pre-starter rations could be seen as an insurance cost to insure improved performance in case of a serious pathogen outbreak. It was our belief that producers and integrators would not make this investment cost if there was no benefit under normal conditions. Thus the objective of this study was to determine the value of additions of porcine spray dried protein plasma during the pre-starter period on the performance of broilers under normal conditions to market weight.

MATERIALS AND METHODS

General Procedures

To determine if industry growth standards could be improved, the experiment was conducted with as hatched Hubbard/Ross broilers obtained from a commercial hatchery. Birds were housed and maintained according to the University of Missouri standard operating procedures and the University of Missouri Animal Care and Use Guidelines. Standard US corn-soy-DDGS-animal byproduct diets were used with the exception of the addition of spray dried plasma protein.

Trial Design

Forty-eight pens of broilers with 30 birds/pen for a total of 1,440 birds were used in a random block design with three treatments and 16 replicate pens. Experimental treatments were fed to 10 days followed by industry standard diets throughout the remaining growout period with ration changes at 21 and 35 days. Each floor pen measured 4 feet wide and 8 feet deep, and contained one metal feeder, one nipple waterer with 5 nipples each 6 inches apart, one heat lamp, and used litter with the cake removed. Supplemental feed trays were used in each pen from 0 to 5 days to encourage acclimation to feed. Heat lamps were used during brood and removed at 14 days of age. Birds received continuous light throughout the trial.

Treatment Descriptions

Experimental diets consisted of an industry standard control diet (C), 0.5% added SDPP (C+.5), or 1% added SDPP (C+1) (Table 4.1). Spray dried plasma protein was obtained from Sonac USA in Maquoketa, IA. The control diet and post-experimental period diets (Table 4.2) were industry standard diets based on Cobb-Vantress (2015) recommendations, formulated on a digestible amino acids basis and a minimum level of CP. Minimum constraints were placed on SDPP to force 0.5 or 1% SDPP addition without regard to cost. Other ingredients were adjusted to maintain consistent energy, CP, Calcium, Phosphorous, Lysine, Methionine+Cystine, and Threonine across all experimental diets. All diets were formulated using least-cost formulation software, and included an industry provided premix.

Measurements

Birds and feed were weighed at time of diet change on 0, 10, 21, 35, and 49 days via electronic scale. Mortality weights were recorded daily and used to adjust feed conversion. Feed intake, body weight gain, feed conversion, and adjusted feed conversion were calculated for each period. At 49 days of age, three birds per pen (48 birds per treatment), of average weight for their pen, were selected for processing. On day 50 birds were processed to determine carcass and parts yield. Parts collected were pectoralis major and minor, thigh, leg, wing, and fat pad.

Statistical Analysis:

The experiment was a complete randomized block design with the position of each block of pens in the barn being the blocking factor. Data was analyzed by analysis of variance (ANOVA) with a one-way design with the pen being the experimental unit throughout the study. All statements are based on the 0.05 level of significance. Mean separations were done as appropriate using the Tukey’s least significant difference test.

RESULTS

Livability

Under normal conditions with no extreme immune challenge, livability was unaffected throughout the trial.

Body Weight

At 10 DOA body weight was significantly improved in the C+.5 treatment compared to C+1 (Table 4.3). After 10 days, no differences were found in BW although C+.5 continued to be the heaviest treatment throughout the experiment. Final BW at 49 DOA was not different at an average of 3.26 kg (Table 4.4), 0.24 kg below the suggested 49 day BW of 3.50 kg (Cobb-Vantress, 2015).

Feed Intake

Feed intake did not differ with exception of 0 to 35 days (Table 4.3). During the 21 to 35 day period C+.5 consumed significantly more (0.0525 kg) than C+1 (Table 4.6). At 49 days all treatments were similar (Table 4.4).

Feed/Gain and Adjusted Feed/Gain

Feed/Gain and adjusted feed/gain were both significantly higher in C+.5 and C+1 compared to C at 10 days (Table 4.3). This effect was not seen at 21 or 35 days (Tables 4.3, 4.4). Feed/Gain was significantly higher in treatment C than C+1 during the 0 to 49 day period due to a slightly higher mortality during the 35 to 49 day period but when adjusted for mortality the adjust feed/gain was insignificant at 49 days (Table 4.4).

Parts Yield

At 50 days of age three birds of average weight from each pen were slaughtered and parts yield measured. All treatments were similar in percentage of hot carcass, fat pad, major, minor and total breast, leg, thigh, and wing (Table 4.7).

DISCUSSION

The objective of this study was to determine if growth performance could be improved in broilers to market weight, under normal conditions, by the addition of porcine spray dried plasma protein during the pre-starter period. Consistent with previous studies of broilers in low pathogen environments (Campbell et al., 2003; Bregendahl et al., 2005a; Bregendahl et al., 2005b), no reliable growth performance improvements were found by the addition of SDPP.

Body weight was significantly higher in the C+.5 treatment compared to C+1 at 10 DOA (Table 4.3). This effect was not seen after 10 DOA (Tables 4.3, 4.4). Consistent with Willemsen and coworkers (2008) findings that BW at seven DOA is the best predictor of BW at 42 DOA, the C+.5 treatment continued to be the heaviest treatment group through to marketing (Table 4.3, 4.4). All treatments mean BW were within 85 grams of each other at an average of 3.26 kg, slightly below the suggested 49 day BW of 3.50 kg (Cobb-Vantress, 2015). From this information we can assume the trial was completed under normal conditions, with standard immune challenge, and the birds grew appropriately

Interestingly, SDPP inclusion caused a significantly poorer feed conversion at 10 DOA (Table 4.3). This is inconsistent with previous studies which have all found SDPP to have insignificant effects on feed conversion during this period (Campbell et al., 2003;

Bregendahl et al., 2005a; Bregendahl et al., 2005b; Campbell et al., 2006; Henn et al., 2013). This may suggest SDPP is not as highly digestible as previously thought. It is worth noting that feed conversion was similar among treatments after 10 DOA and adjusted feed/gain was numerically poorer in the control treatment than the treatments receiving SDPP in the 0 to 49 day period (Table 4.4).

Based on the similarity of BW and feed conversion after 10 DOA despite significant differences in the 0 to 10 day period, today's broiler appears to have an outstanding ability to compensate and achieve flock uniformity. This is likely due to the remarkable improvements in broiler genetics (Havenstein et al., 2003b, a) leading to a drive in the broiler to maximally consume feed and grow accordingly. Studies in how today's broiler adjusts and compensates to deficient or excess energy and protein may lead to a better understanding of how to improve growth through marketing or how to more cheaply feed the birds with early intervention strategies.

As Henn and coworkers (2013) suggests, the effects of SDPP may be more evident with a high immune challenge or poor quality chicks. Improved livability and growth performance has been observed in multiple studies of broilers in environments with a high immune challenge (Campbell et al., 2003; Bregendahl et al., 2005a; Bregendahl et al., 2005b; Campbell et al., 2006). Spray dried plasma protein has not been researched with poor quality chicks versus normal quality chicks, this could be a useful tool for integrators and producers. The use of SDPP in pre-starter diets of chicks from older breeder flocks, when chick quality tends to decline, could improve their performance similar to the improvements seen in high pathogen environments and should be further researched.

CONCLUSION

Based on previous studies, inclusion of SDPP in the pre-starter ration may be useful as insurance in case of a high immune challenge. Under normal conditions though, it is not recommended to include SDPP in only the starter ration. In the current study, consistent, significant improvements in growth were not observed and inclusion of SDPP raised the pre-starter diet cost.

Table 4.1. Ingredient composition and nutrient profile of experimental diets fed to broilers to 10 days of age.

	Treatments		
	C	C+0.5	C+1
Ingredient	%	%	%
Corn	56.09	56.68	57.26
Soybean Meal	25.38	24.48	23.59
Porkmeal	5.00	5.00	5.00
Corn DDGS	10.00	10.00	10.00
Lard	1.34	1.16	1.00
Dicalcium Phosphate	0.15	0.13	0.11
Sodium Chloride	0.30	0.30	0.30
Limestone	0.94	0.95	0.97
Vitamin/Mineral Premix[1,2]	0.25	0.25	0.25
DL-Methionine	0.22	0.23	0.24
Lysine HCL	0.21	0.20	0.19
Threonine	0.07	0.06	0.05
Avatec	0.05	0.05	0.05
Plasma Protein	0.00	0.50	1.00
Nutrient			
ME (kcal/kg)	3095	3095	3095
Crude Protein	22	22	22
Calcium	1.00	1.00	1.00
Available Phosphorus	0.45	0.45	0.45
Lysine	1.32	1.32	1.32
Methionine + Cysteine	0.98	0.98	0.98
Threonine	0.86	0.86	0.86
Valine	1.12	1.13	1.13

[1] Vitamins provided per kilogram: Vitamin E 6,600 IU; B-12 4.4 mg; A 3,083,700 IU; D3 1,101,000 ICU; Thiamin 440 mg; Riboflavin 2,643 mg; Niacin 11,000 mg; Pantothenate 2,643 mg; Pyridoxine 550 mg; Biotin 13 mg; Folate 275 mg; Choline 154,185 mg

[2] Minerals provided per kilogram: Mn 40,000 mg; Zn 40,000 mg; Fe 20,000 mg; Se 60 mg; Cu 4,500 mg; Iodine 600 mg

Table 4.2. Ingredient composition and nutrient profile of common diets fed to all broilers in all treatments from 11 to 49 days of age.

	Period		
	11-21	22-35	36-49
Ingredient	%	%	%
Corn	62.89	69.63	72.86
Soybean Meal	17.87	19.56	17.88
Porkmeal	7.00	7.00	7.00
Corn DDGS	10.00	1.95	0.20
Lard	1.00	1.00	1.20
Dicalcium Phosphate	0.00	0.00	0.00
Sodium Chloride	0.30	0.30	0.30
Limestone	0.11	0.00	0.00
Vitamin/Mineral Premix[1,2]	0.25	0.25	0.25
DL-Methionine	0.20	0.15	0.13
Lysine HCL	0.25	0.07	0.08
Threonine	0.08	0.04	0.05
Avatec	0.05	0.05	0.05
Plasma Protein	0.00	0.00	0.00
Nutrient			
ME (kcal/kg)	3138	3180	3210
Crude Protein	20	19	18
Calcium	0.84	0.77	0.76
Available Phosphorus	0.49	0.40	0.38
Lysine	1.19	1.05	1.00
Methionine + Cysteine	0.89	0.82	0.78
Threonine	0.78	0.71	0.68
Valine	1.00	0.96	0.91

[1] Vitamins provided per kilogram: Vitamin E 6,600 IU; B-12 4.4 mg; A 3,083,700 IU; D3 1,101,000 ICU; Thiamin 440 mg; Riboflavin 2,643 mg; Niacin 11,000 mg; Pantothenate 2,643 mg; Pyridoxine 550 mg; Biotin 13 mg; Folate 275 mg; Choline 154,185 mg

[2] Minerals provided per kilogram: Mn 40,000 mg; Zn 40,000 mg; Fe 20,000 mg; Se 60 mg; Cu 4,500 mg; Iodine 600 mg

Table 4.3. Growth performance[1] from 0 to 21 days of broilers fed control (C), 0.5% addition of SDPP (C+.5), and 1% addition of SDPP (C+1) from 0 to 10 days.

Period	0 to 10 days				0 to 21 days			
	C	C+.5	C+1	Pooled SE	C	C+.5	C+1	Pooled SE
Livability (%)	0.981	0.987	0.988	0.024	0.977	0.969	0.983	0.030
Body Weight (kg)	0.207^{ab}	0.214^{a}	0.198^{b}	0.011	0.736	0.738	0.724	0.042
Feed Intake (kg)	0.199	0.211	0.201	0.017	0.941	0.961	0.942	0.040
Feed/Gain	1.188^{a}	1.265^{b}	1.312^{b}	0.086	1.361	1.390	1.387	0.096
Adjusted Feed/Gain	1.170^{a}	1.256^{b}	1.306^{b}	0.083	1.351	1.379	1.378	0.094

$^{a\text{-}b}$ Means within a row with no common superscripts differ significantly by Tukey method ($p<0.05$).

[1] Data are means of eight replicate pens initially containing 33 broilers per pen.

Table 4.4. Growth performance[1] from 0 to 49 days of broilers fed control (C), 0.5% addition of SDPP (C+.5), and 1% addition of SDPP (C+1) from 0 to 10 days.

Period	0 to 35 days				0 to 49 days			
	C	C+.5	C+1	Pooled SE	C	C+.5	C+1	Pooled SE
Livability (%)	0.965	0.956	0.976	0.031	0.908	0.916	0.917	0.057
Body Weight (kg)	1.890	1.893	1.869	0.078	3.219	3.303	3.264	0.140
Feed Intake (kg)	2.908^{ab}	2.976^{a}	2.864^{b}	0.096	5.937	5.921	5.751	0.337
Feed/Gain	1.576	1.596	1.570	0.052	1.844^{a}	1.817^{ab}	1.772^{b}	0.068
Adjusted Feed/Gain	1.558	1.574	1.563	0.048	1.753	1.748	1.736	0.054

$^{a\text{-}b}$ Means within a row with no common superscripts differ significantly by Tukey method ($p<0.05$).

[1] Data are means of eight replicate pens initially containing 33 broilers per pen.

Table 4.5. Growth performance[1] separated by feeding period from 0 to 21 days of broilers fed control (C), 0.5% addition of SDPP (C+.5), and 1% addition of SDPP (C+1) from 0 to 10 days.

Period	0 to 10 days				10 to 21 days			
	C	C+.5	C+1	Pooled SE	C	C+.5	C+1	Pooled SE
Livability (%)	0.981	0.987	0.988	0.024	0.977	0.976	0.973	0.030
Body Weight Gain (kg)	0.207^{ab}	0.214^{a}	0.198^{b}	0.011	0.529	0.549	0.535	0.054
Feed Intake (kg)	0.199	0.211	0.201	0.017	0.741	0.748	0.734	0.033
Feed/Gain	1.188^{a}	1.265^{b}	1.312^{b}	0.086	1.411	1.407	1.412	0.123
Adjusted Feed/Gain	1.170^{a}	1.256^{b}	1.306^{b}	0.083	1.406	1.399	1.403	0.122

[a-b] Means within a row with no common superscripts differ significantly by Tukey method ($p<0.05$).

[1] Data are means of eight replicate pens initially containing 33 broilers per pen.

Table 4.6. Growth performance[1] separated by feeding period from 21 to 49 days of broilers fed control (C), 0.5% addition of SDPP (C+.5), and 1% addition of SDPP (C+1) from 0 to 10 days.

Period	21 to 35 days				35 to 49 days			
	C	C+.5	C+1	Pooled SE	C	C+.5	C+1	Pooled SE
Livability (%)	0.965	0.956	0.976	0.031	0.908	0.916	0.917	0.057
Body Weight Gain (kg)	1.144	1.151	1.150	0.059	1.348	1.432	1.383	0.115
Feed Intake (kg)	1.944^{ab}	1.978^{a}	1.925^{b}	0.059	2.742	2.828	2.807	0.162
Feed/Gain	1.712	1.711	1.683	0.074	2.293	2.176	2.089	0.277
Adjusted Feed/Gain	1.688	1.687	1.675	0.064	1.998	2.004	2.019	0.133

[a-b] Means within a row with no common superscripts differ significantly by Tukey method ($p<0.05$).

[1] Data are means of eight replicate pens initially containing 33 broilers per pen.

Table 4.7. Processing yields[1] of broilers at 50 days of age, after 12 hours fasting, fed control (C), 0.5% addition of SDPP (C+.5, and 1% addition of SDPP (C+1) from 0 to 10 days.

	C	C+.5	C+1	Pooled SE
Hot Carcass[2]	71.00	70.96	70.57	1.31
Fat Pad[3]	2.49	2.49	2.62	0.68
Major Breast[3]	27.71	26.95	26.64	2.20
Minor Breast[3]	5.85	5.73	5.68	0.75
Total Breast[3]	33.55	32.74	32.47	2.68
Leg[3]	13.92	14.16	14.18	1.20
Thigh[3]	19.29	19.06	18.87	1.57
Wing[3]	11.59	11.61	11.28	0.89

[a-b] Means within a row with no common superscripts differ significantly by Tukey method ($p<0.05$).

[1] Data are means of 48 carcasses per treatment.

[2] Expressed as a percent of live weight.

[3] Expressed as a percent of the hot carcass weight.

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