GENETICS AND PRODUCTION SYSTEM INTERACTION UPON CARBON BALANCE OF GROWING BROILERS

By

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GENETICS AND PRODUCTION SYSTEM INTERACTION UPON CARBON BALANCE OF GROWING BROILERS

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Abstract:

A total of eight hundred chicks were obtained from a commercial hatchery in Siloam Springs, AR. Half of the chicks were Cobb 500 and half were Ross 308 breed. Each of the four hundred birds was composed of half male and female. Chickens for the performance study were housed in two barns to represent two separate production systems. One barn was designed to simulate a Cobb 500 breed production system, a lower protein to energy ratio and light restriction (LRLP; light restriction, low protein) and the other barn was a Ross 300 breed production system, which specified a nearly constant lighting program (23 h) and a higher dietary protein to energy ratio (CLHP; constant light, high protein). For the carbon balance study, chickens were placed into forty metabolic chambers housed in two environmentally controlled separate rooms. Each room had 20 chambers, 12 broiler chambers (28.6 X 37.4 X 44) and 8 turkey chambers (46 X 63.8 X 66). One room was designated the LRLP environment while the other was the CLHP. Body weight, feed consumption, feed conversion ratio, and carcass characteristics were determined for birds days 0-41.

Birds under the CLHP treatment had greater ($P<0.05$) body weight. Environment had little effect on feed conversion ratio ($P<0.05$). On days 7, 13, 20, and 27 CLHP birds retained more ($P<0.05$) carbon than LRLP birds. However, on day 41, although only numerical, LRLP retained more ($P>0.10$) carbon than CLHP birds. Ross birds retained more ($P<0.05$) on days 7 and 13. However, on day 41, Cobb birds retained 1% more ($P>0.10$) carbon than Ross birds. On days 7, 13, and 20, with CLHP birds produced more ($P<0.05$) gaseous carbon versus the LRLP birds and Ross birds produced more ($P<0.05$) gaseous carbon. On days 7, 13, and 20, CLHP birds excreted 12% more ($P<0.05$) carbon than LRLP. Little differences were seen on day 41, but lighting must be a factor in overall carbon emissions. Therefore, raising Cobb breed males under light restriction and lower protein diet will produce a viable product in efficient time with a decrease in greenhouse gas emissions.

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CHAPTER I

INTRODUCTION

The expansion of the agricultural industry over the last 100 years has been made possible through the numerous contributions of scientists, researchers, engineers, corporations, and government officials. Crops are now mass-produced in order to meet the increasing demands of humanity. Currently, food production surpasses the world population. However, according to the United Nations, by the year 2050, the global population of people will be 9 billion (FAO, 2009). A large factor involved in amount of food available to population distribution is the quantity and quality of the inputs used for the food production industry. These inputs include: land, natural resources (water, etc.), industrial resources such as, mechanization and facilities, and grain production (USDA, 2002). Agriculture has been able to grow and expand due to the necessity of a larger industry. Nevertheless, agriculture will need to adapt to the even faster growing demand for food (FAO, 2009). The days of small-scale production are now defunct; large-scale production is the forefront for the future of the agricultural industry, and with this large-scale production the consequence can be an increase in greenhouse gas emissions.

The 20th century has proven to be an era of incredible growth for the poultry industry. The greatest growth and prosperity has occurred over the past 50 to 75 years (Etches, 1998; Hammerstedt, 1999; and Rishell, 1997). The current prosperity of the industry may be largely attributed to the application of advancements in biological knowledge. Particular credit can be given to the focus of scientists on the metabolic processes occurring at a molecular level in animals. The discoveries resulting from such focus also resulted in the development of a massive biochemical and pharmaceutical industry. The advancements made by all of these contributors have allowed the industry to develop from the small, "backyard" farms into the current production schemes that incorporate large amounts of both mechanical and biological technology to run commercial farms capable of producing thousands of broilers every year. Because of the expansion, poultry meat is now the most commonly consumed meat in many countries (Etches, 1998).

Primarily, the broiler industry has benefitted from advancements in genetic selection capabilities. The industry has strategically applied genetic selection to produce fast-growing broilers throughout the last 50 years (Rishell, 1997). Geneticists are able to study the chickens and select birds that will produce offspring capable of developing into the desired end product. Although much of the industry's success has been attributed to genetic improvements, the chickens could not perform to their highest potential without proper environmental conditions, which could be causing an increase in the poultry industries greenhouse gas emissions. Improving environmental conditions to increase the efficiency of the broiler could decrease these emissions.

The role of the biologist, geneticist, nutritionist, farm manager, and veterinarian is to assure that the genetic potential of the chicken can be achieved through proper management in all aspects of production. Integrating and implementing the knowledge of each of these fields has been a major reason why the poultry industry has been able to advance in both scale and efficiency of production. The scientists within the industry have performed quite well in terms of advancement. Havenstein et al. (2003) compared the carcass compositions of birds eating a typical diet from 1957 to one from 2001. The study used two separate lines of birds common to each time period. The birds consuming the 2001 diet were superior to the 1957 birds in terms of carcass weights, hot carcass yield, breast meat yield, saddle and leg yield, and whole carcass fat yield. The study concluded that the typical broiler has increased in size over time, yielding more end product to be sold. This fact has been achieved thanks to the combined efforts of the geneticists, nutritionists, biochemists, veterinarians, etc. But did this increase in available product attribute to an increase in greenhouse gas emissions?

CHAPTER II

REVIEW OF LITERATURE

Carbon dioxide production

For millions of years plants have been able to produce oxygen through photosynthesis. Photosynthesis begins with light and carbon dioxide being absorbed by plant cells. Then through a set of reactions, Calvin cycle or Reverse Krebs cycle, oxygen can be produced. This process of producing oxygen has been used by millions of people and animals throughout the world, with a balance between production and consumption. However, over the past decade, the human population has more than doubled and is projected to continue to grow to 9 billion by the year 2050 (FAO, 2009), thus increasing oxygen demands. This doubling in oxygen consumption and carbon dioxide production has caused an imbalance in the homeostasis between oxygen production, from carbon dioxide, and oxygen consumption, with more oxygen consumed and leaving more CO_2 in the atmosphere.

Where does all the atmospheric carbon dioxide go? Atmospheric CO_2 is absorbed by oceans and are emitted back into the atmosphere (Dunckley, 2011). Through a complex series of reactions the carbon cycle can dissolve this atmospheric carbon.

Upon the dis-solution in water, CO_2 forms a weak acid that reacts with carbonate anions and water to form bicarbonate (Falkowski et. al, 2000). Next in an attempt to buffer the changes in the CO_2 concentration, the carbonate system depends on the addition of cations from slow weathering rocks (Falkowski et. al, 2000). Due to the increased rate in CO_2 emissions into the atmosphere, the supply of these cations is much lower; causing the ability to absorb the excess CO_2 decrease as the atmosphere CO_2 continues to rise (Falkowski et. al, 2000). The ratio between the rate at which these reservoirs absorb atmospheric CO_2 and the rate of emissions determines the overall rate of change of atmospheric CO_2 (Falkowski et. al, 2000). This excess CO_2 gas can prevent heat from radiating or reflecting away from earth and thus result in atmospheric warming (global warming). The excess CO_2 has caused a 36% increase in temperature since the industrial revolution (Dunckley, 2011).

Atmospheric CO_2 regulation

A tool for further assessing the potency of certain gaseous emissions is greenhouse equivalents (Grubb et al., 1999; Dunkley, 2011). Expressions of the 100 year global warming potential for certain gases can be obtained by those values. They are derived from understanding that CH_4 is 21 times more potent than CO_2 and N_2O is 310 times that. These values are just another measure of gaseous emissions and can be used as another investigative tool for understanding ways to reduce emissions.

The over abundance of carbon dioxide is playing a role in global warming (Metcalf, 2008). In the last century, the over production of greenhouse gases (GHG), such as carbon dioxide, methane, and nitrous oxide has led to global warming effects (Koneswaran and Nierenberg, 2008). These effects include the rising of sea levels, tundra thawing, hurricanes, and rising temperatures. Global warming concerns led legislators to propose a tax on greenhouse gas emissions (EPA, 2011). The total GHG emissions for 2011 being 6,702.3 million metric tons CO_2 Equivalence (CO_2E), with 83.7% of that total being CO_2, an increase by 8.4% from 1990 to 2011 (EPA, 2011). The proposed carbon tax is starting at $15 per metric ton that will gradually increase over time, but will have refundable portions for sequestering carbon emissions such as, carbon credits (Metcalf, 2008; Dunkley, 2011). With emissions of CO_2 being slightly more than 5,000 million metric tons in 2011 (Energy Information Administration, 2011), a charge of $15 per metric ton would raise $84 billion in tax revenues (EPA, 2011).

Agriculture contributions to greenhouse gas emissions

Today 56 billion land animals are reared and slaughtered for human consumption annually, with the human population expected to double by 2050 (FAO, 2009), the number of animals needed to meet this expectation must also double (Koneswaran and Nierenberg, 2008). Along with the increases in food demand comes an increase in oxygen consumption and CO_2 production, ultimately an increase in greenhouse gas production. As a result, the increase in food demand will exponentially cause the demand for production of food to increase drastically. By 2030, the increase in demand for meat is expected to increase livestock production 85% when compared to year 2000 meat consumption (Friel, et al., 2009). Making animal sources a major contributor to carbon emissions. The agriculture sector contributes 6.9% of total US greenhouse gas emissions, with an approximate 19% increase since 1990 (EPA, 2011). These emissions can be seen throughout all stages of animal production, in essence, farm to fork. This includes: the chemicals sprayed on crops grown to feed the livestock, transporting the animals to slaughter, transportation from slaughter to retail, and refrigeration of meats. However, each type of livestock accounts for different amounts of emissions; therefore, they should be looked at individually. Knowing the carbon footprint of the poultry industry can help reduce the amount of energy or carbon use and improve overall production costs (Dunkely, 2011).

The poultry industry has developed commercial broiler breeds capable of performing at efficiency levels that were unheard of 50 years ago. Intensive genetic selection, diet formulation, and management programs by farm managers enable these birds to perform to their full genetic potential. Each of the aforementioned advances could be instrumental in lowering the carbon footprint of commercial broiler production (Dunkley, 2011).

Global production of broilers

On the global scale, the agricultural production industry relies on the inputs needed to achieve success. The animal production industry especially relies on available nutrient input. The most important inputs for meat production include capital and feed, which rely on availability of land and labor. These aforementioned are all dependent on availability of natural resources, with urbanization expected to increase about 70 percent (FAO, 2009), making the world population more urban, causing less available land to grow nutrients for the increase in demand for food production. The regions of the world that can most efficiently supply these resources are able to generate the most product (Dyck et al., 2003) from less land and available resources. As resources become more efficiently available throughout the world, meat production will need to rise by over 200 million tons (FAO, 2009).

The poultry industry can be a direct model for the increase of production with increased efficiency and the potential to decrease greenhouse gas emissions (Dunkley, 2011). The poultry industry has grown and become very successful because of both low-cost labor and the availability of feed products from close proximity to production facilities. But, climate change can affect these agriculture systems. In order to respond to the new demand for food, farmers will need new technologies to produce more from less land (FAO, 2009), which ultimately can cause an increase in greenhouse gas emissions. The industry has been able to flourish globally because the meat is produced and available at a lower cost than pork or grain-fed beef. This fact means less capital is required to produce a valuable protein source (Dyck et al., 2003).

Because poultry meat is less costly to produce compared to pork and grain-fed beef, the global consumption of poultry has increased in recent years (Etches, 1998). Poultry meat consumption per capita grew faster in all three classes of countries (high-, middle-, and low-income) than consumption of all other meats between 1961 and 2000. This increase was 370, 635, and 201 percent for high-, middle-, and low-income countries, respectively. Although total meat consumption per capita increased worldwide, it is clear that poultry meat consumption was significantly higher than the other meat products (Taha, 2001).

Poultry meat production in the US

Poultry production in the U.S. is higher than any other area in the world. The total farm value is greater than $20 billion. The U.S. is second to Brazil in broiler export (USDA, 2012). This fact demonstrates the need and use of broiler products within the

U.S. The annual production of broilers has steadily increased over the years. Between 2004 and 2008, the production of broilers ranged from 4.8 to 7.0 billion pounds, accounting for 14% to 17% of total meat production (USDA, 2012). The annual production of poultry meat in December 2012, reached 2,853 million pounds, with beef production reaching 2,020 million pounds and pork 1,954 million pounds (USDA, 2012), showing poultry meat production still far exceeds the meat production of those industries. That same year, the USDA reported annual per capita consumption of broiler meat to be 93.6 pounds, while the annual per capita consumption of pork slightly decreased from 63.8 pounds in 2008 to 59.2 pounds. Beef consumption was 82.0 pounds per capita in 2012. One reason broiler meat is in high demand is because it is less expensive than beef (USDA, 2007). Additionally, broiler meat is readily available almost anywhere in the country.

The industry must strive to meet the increasing demand for poultry products. Without the ability to produce a valuable end product, the industry cannot thrive. Proper growth and development of the chickens is a critical precursor to the desirable end product, and the health of the birds is imperative to maximum performance potential. The environmental conditions that the birds are raised in must also be considered, and the effects of the emissions from these environments. One area of major concern that may retard the growth of chickens is disease. Numerous preventatives and vaccines for many diseases have been produced through scientific research and development; however, much about the transmission, adaptability, and emergence of diseases remains unascertained, making it difficult to keep some diseases at bay. The industry strives to employ the most current techniques in disease prevention and treatment in an effort to efficaciously produce poultry meat for consumption. Developing new techniques and methodologies will help not only improve the efficiency of the industry but, also mitigate unavoidable consequences like being taxed on amount of greenhouse gas emissions.

Broiler production contribution to carbon emissions

The United States produced 8.5 billion broilers, with Americans consuming 43.5 kilograms of chicken in the year 2003 (Lima, et al., 2008). In the following years the amount produced and the size of the birds increased (Lima et al., 2008). The broiler industry has multiple areas of carbon emissions including: the chick's arrival to the broiler house, heating and cooling of the broiler house, excreta, feeding, moisture content, and transportation. Live body weight is a common variable in these emissions (Roumeliotis, et al., 2010). Size of birds and number of birds can affect the amount of greenhouse gas emissions. Larger animals produce more greenhouse gas, with the amount emitted increasing with the more animals grown (Dunkley, 2011). Within this system, there is waste disposal and composting processes. Waste represents one of most significant amount of emissions, with ammonia and methane being produced by the microbial population in the excreta (Roumelotis et. al, 2010). Disposal of wastes consists of using it as a feed source, or an organic fertilizer. Chicken litter contains nitrogen, phosphorus and potassium, all useful for soil and animals. Using chicken litter as a feed source remarkably lowers carbon waste for broiler farmers (Lima et. al, 2008). In general, poultry production accounts for five carbon dioxide equivalents (tons of carbon dioxide per ton of carcass weight or 20,000 eggs) versus beef production, which produces over 15 equivalents (Friel et al., 2009). This may be due to the ability to utilize the greenhouse gas emissions for other viable uses, which lowers the carbon emissions and ultimately decrease the overall cost of production.

Strategies To Reduce Carbon Emissions

Efficiency of broilers

Flock managers face decisions regarding broiler husbandry daily. Decisions that ultimately impact growth and the efficiency of feed utilization for maintenance and production. Overall efficiency of the broiler is affected by numerous factors. These factors include broiler management, and environmental and feeding programs. Environmental factors pertain to temperature and lighting, while feeding programs consists of mash versus pellets and high energy versus low energy diets. Feed processing, like pelleting, have been touted for beneficial effects on poultry performance (Acar, et al., 1991; Scheideler, 1995; Moritz, et al., 2001). Likewise numerous managerial – husbandry decisions related to stocking density (Cravener, et al., 1992; Puron, et al., 1997), lighting program (Ingram, et al., 2000), and ventilation are well known to impact body weight and feed conversion ratio (FCR). Though the precise mode of action by which such nonnutritive factors impact poultry performance and carbon footprint is critical to successful poultry production they must be studied to determine their impact. Furthermore, production practices such as improved feed efficiency, more accurate knowledge of specific animal requirements and decreasing the practice of over-formulating rations will dramatically decrease nutrient excretion and aid the carbon footprint (Knonegay and Harper, 1997). Since growth rate and FCR are also related to nutrition, the traditional approach of separating nonnutritive factors that impact average daily gain, FCR, and ultimately the carbon footprint, from nutrition must be questioned.

Temperature

Much of the CO_2 the poultry industry generates is primarily from the utilization of fossil fuels to generate heat for the broiler house (Dunkley, 2011). Results from a study at the Univesity of Georgia stated that propane gas from heating poultry houses generated the most GHG on broiler farms, 68% of the emissions being from propane use for brooding (Dunkley, 2011). Increasing atmospheric temperatures cause an increase by the animal to dissipate heat by panting which increases the amount of CO_2 entering the atmosphere. Moreover, an increase in temperature can also decrease feed consumption, and overall decrease in body weight gain and performance, all which are vital to the survival of the animal to be utilized as food. As most of the world's poultry is now concentrated in tropical and semitropical countries, most of the modern genetic lines of poultry have been selected for temperate climates (Balnave, 2004; Science, 2004). According to the Cobb Vantress broiler management guide (2010), chicks one day of age require a temperature of 34ºC with humidity ranging from 30 to 50%, while chicks at 42 days of age, need a temperature of 18ºC with a humidity ranging from 50 to 70%, for optimum performance. Research conducted by Cerrate and Waldroup (2010), stated birds reared in a cyclic temperature can respond better than constant temperature-reared birds during heat stress. In another study, it is further explained that birds grown in an air velocity tunnel gained more weight from 4 to 6 weeks of age than chickens that were grown in a traditional floor cage environment (Simmons, et al., 2003). Furthermore, energy requirements of broilers decrease as the ambient temperature increases above 21ºC (Zaman, et al., 2008).

Lighting

Broiler chickens are kept on a continuous or near continuous lighting schedule to maximize feed intake and growth rate (Ohtani and Leeson, 2000). When lights are on, birds tend to eat and drink; however, when the lights are off, birds tend to lie down and rest. Research has been conducted to determine the most effective lighting program on the feed conversion ratio (FCR). Two types of lighting systems exist, intermittent and continuous. Intermittent lighting consists of short light and dark cycles (12 hours light: 12 hours dark). Continuous lighting or conventional lighting program, consist of 23 hours light, 1 hour dark (23 light: 1 dark). Non-intermittent restricted lighting program on male broilers decreased body weight when compared to conventionally lighted broilers (Ingram, 2000). Furthermore, the 12 light:12 dark reared birds had an improved feed conversion over the 23 light:1 dark birds (Ingram et al., 2000). In another study, the body weights of intermitted lighting birds at 6 to 8 weeks of age were heavier than continuous light (Ohtani and Leeson, 2000). This data indicates that bodyweight and FCR are associated with less activity of the intermittent lighting chickens during the dark period compared to that of the continuous lighting chickens (Ingram et. al, 2008; Ohtani and Leeson, 2000). Furthermore, this indicates the ratio of carbon dioxide produced while walking to the feeder and drinking, to feed carbon consumed, can be impacted by the lighting program. Large amounts of energy in the form of lighting and ventilation must also be considered in the GHG emissions. One pound of chicken meat produced 7.05 pounds of CO_2 (Poultry Site, 2010). Moreover, power plants accounted for 2.2 billion metric tons of CO_2 equivalance, which represents 67% of the 3.3 billion metric tons reported for 2011 (EPA, 2011). Therefore, producing the most product using the optimum lighting program can greatly reduce these emissions and ultimately give more carbon credits to producers.

Feed Type

Energy is one of the most important considerations when formulating broiler rations. This is usually expressed in diets as metabolizable energy (Lopez and Leeson, 2008). Metabolizable energy is an expensive part of a broilers ration and adds to the overall production cost. Furthermore, metabolizable energy is used to determine energy requirements for maintenance and production. Although net energy offers the most accurate way to account for calorie energy for avian's, they excrete both urine and feces out of the cloaca simultaneously. It does not allow for the simple metabolizable energy equations to be used (gross energy minus the energy excreted as feces and urine). Manure has a high content of methane, with this the Global Warming Potential (GWP) to estimate the output from methane emissions, calculated over a specific time period is 25 times as much GWP as CO_2 (Dunkley, 2011). Net energy accounts for calories lost as heat due to maintenance of basal metabolism, activity, and production (i.e., tissue and eggs). Although the net energy system does quantify the energy inefficiencies, the difficulty is in establishing the experimental environment (carolimetric chambers) to collect this data.

Pelleting is the most common form of poultry diets. A general definition of the pelleting process is "the agglomeration of small particles into larger particles by the means of a mechanical process in combination with moisture, heat, and pressure" (Falk, 1985). Pelleting was introduced to the US in the 1930's and today virtually all broiler and turkey feeds undergo this process. It has been documented that pelleting feed has improved weight gain to feed ratios versus mash fed diets (Briggs, et al., 1999). The reasons for the improvements can be attributed to the increase in digestibility, decrease in ingredient segregation, and increased palatability (Briggs, Behnke, Watkins and Maier, 1999), making pelleting another way to reduce GHG emissions by increasing bird efficiency even more.

Improved body weight and FCR performance are associated with processed feeds (McKinney and Teeter, 2004). Pelleted rations versus a mash ration has difference in bodyweight and FCR (Jafarnejad, et al., 2010). In a study conducted by Lemme et. al., (2006), broilers fed high quality pellets had a high feed intake, and broilers fed mash or crumble diet had a lower feed intake. The enhancement of feed value and reduced need by the animal may be attributable to these results. In accepting that pelleting enhances bird performance by reducing activity energy expenditure, emphasis must be given to pellet quality. Indeed, obtaining feeds where zero pellet breakage occurs is practically unattainable.

CONCLUSIONS

Animal meat is an affordable way to gain protein, iron, and vitamins, all vital nutrients needed to be healthy. Therefore, growing livestock for consumption is important and needed. Understanding how GHG are generated and what the poultry industry can do to further reduce the poultry industries emissions remains important. A “Carbon Credit” unit represents a certified reduction in GHG emissions. If these can be given to producers who voluntarily take action to reduce emissions then overall production costs would be lowered (less being taxed) and ultimately a cheaper product for the public to purchase with the ability to help the environment. Further investigation of areas where the most GHG emissions are being produced is vital to producers and consumers.

CHAPTER III

GENETICS AND PRODUCTION SYSTEM INTERACTION UPON CARBON BALANCE OF GROWING BROILERS

ABSTRACT

A total of eight hundred chicks were obtained from a commercial hatchery in Siloam Springs, AR. Half of the chicks were Cobb 500 and the remaining half were Ross 308 breed. Each of the four hundred birds was composed of half male and female. Chickens for the performance study were housed in two barns were arranged with 36 floor cages each to represent two separate production systems for a total of 72 pens. One barn was designed to simulate a Cobb 500 breed production system, which specified a lower protein to energy ratio and light restriction (LHLP) the other barn was designed to simulate a Ross 300 breed production system, which specified a nearly constant lighting program (23 h) and a higher dietary protein to energy ratio (CLHP). For the carbon balance study chickens were placed into forty metabolic chambers were housed in two environmentally controlled separate rooms. Each room had 20 chambers, 12 broiler chambers (13’’X 17’’X 20’’) and 8 turkey chambers (21’’X 29’’X 30’’).

One room was designated to simulate the LRLP environment while the other was to simulate the CLHP. Treatments remained the same as in the performance study. Body weight, feed consumption, FCR, and carcass characteristic's were determined for birds days 0-41. Birds under the CLHP treatment had greater ($P<0.05$) body weight. During the grower phase (days 20 and 27) CLHP birds were ($P<0.05$) heavier compared to LRLP birds. However, during the finisher phase there was no difference ($P>0.10$) between environments. Throughout the experiment, environment had little effect on FCR ($P<0.05$); however, FCR for CLHP birds was numerically lower and only a breed difference ($P<0.05$) on day 0-34 with Cobb birds having a lower ($P<0.05$) FCR was noted. CLHP birds contained more ($P<0.05$) carcass protein on day 7, 13, 20, and 22 than LRLP birds. Similarly, there was a difference between the two strains, with Ross birds containing more ($P<0.05$) carcass protein on days 7 and 13 than Cobb birds. Apart from the younger bird, carcass protein on day 41 Cobb birds contained more, although only numerical ($P=0.67$). Carcass fat during the starter and grower phases increased for birds exposed to the CLHP environment than LRLP, uncovering a 19% difference at the end of the starter period. On days 7, 13, 20, and 27 CLHP birds retained more ($P<0.05$) grams of carbon than LRLP birds. However, on day 41, although only numerical, LRLP retained more ($P>0.10$) grams of carbon than CLHP birds. Ross birds retained more ($P<0.05$) grams of carbon on days 7 and 13. However, on day 41, Cobb birds retained 1% more ($P>0.10$) grams of carbon than Ross birds. On days 7, 13, and 20, with CLHP birds produced more ($P<0.05$) grams of gaseous carbon versus the LRLP birds. However by day 41, there were no differences between CLHP and LRLP ($P>0.10$) grams of gaseous carbon ($P>0.10$). Ross birds produced more ($P<0.05$) grams of gaseous carbon on days

20, 27 and 34 than Cobb birds. On days 7,13, and 20, CLHP birds excreted 12 percent more ($P<0.05$) carbon than LRLP. Furthermore, Ross birds excreted more ($P<0.05$) grams of carbon regardless of environment on days 7, 13, 20, and 27. . Little differences were seen on day 41, but lighting must be a factor in overall carbon emissions. Therefore, raising Cobb breed males under light restriction and lower protein diet will produce a viable product in efficient time with a decrease in greenhouse gas emissions.

INTRODUCTION

The abundance of carbon dioxide is playing a major role in global warming (Metcalf, 2008). According to the EPA (2011) the total greenhouse gas emissions were 6,702.3 million metric tons of CO_2 Equivalence (CO_2E), with 83.7% of that total being carbon dioxide. In December 2012, the amount of poultry meat production was 2,853.3 million pounds (USDA, 2012), but with the global population expected to double to 9 billion (FAO, 2009) poultry meat production will also need to increase and with this increase will be an increase in carbon emissions. Furthermore, the government has proposed a carbon tax that starts at $15 per metric tons to attempt to regulate these emissions (EPA, 2011). Additionally, with emissions of carbon dioxide at approximately 5,000 million metric tons in 2011 (Energy Information Administration, 2011) the proposed carbon tax would raise approximately raise $84 billion in tax revenue. This carbon tax has caused awareness within the broiler industry to decrease carbon dioxide emissions in order to decrease the production cost.

The environmental conditions that the birds are raised in must be considered as means to modify emissions. This environment includes lighting, temperature, and diet.

Lighting consists of intermittent lighting versus constant lighting, and diet consists of high protein verse low protein. Breed of birds, Cobb-500 verses Ross-308, must also be considered as another major means to modify emissions. Deciding what environment and breed of bird that can be grown efficiently to meet the growing consumer demand along with having the lowest emissions is key to mitigating the coming increase in taxes, increase in production cost, and ultimately an increase in cost for the consumer.

The objective of this study was to determine the environment: intermittent lighting or constant lighting, high protein to energy ratio or low protein to energy ratio, breed: Cobb-500 or Ross-308, and sex would emit the least amount carbon dioxide emissions along with growing efficiently.

MATERIALS AND METHODS

A total of eight hundred chicks were obtained from a commercial hatchery in Siloam Springs, AR. Half of the chicks were Cobb 500 and the remaining half were Ross 308 breed. Each of the four hundred birds was composed of half male and female. All chicks were placed in boxes of one hundred and transported to the study site at Oklahoma State University.

Performance Study

Two barns were arranged with 36 floor cages each to represent two separate production systems for a total of 72 pens. One barn was designed to simulate a Cobb 500 breed production system, which specified a lower protein to energy ratio and light restriction (LRLP) (Table 1, Table 2). In contrast, the other barn was designed to simulate a Ross 300 breed production system, which specified a nearly constant lighting program (23 h, Table 2) and a higher dietary protein to energy ratio (CLHP, Table 3).

Upon arrival of the chicks at Oklahoma State University, both Cobb and Ross breed birds were randomly selected from each box in a group of ten, wing banded, individually weighed and placed into one of the floor pens starting in the barn designated for LRLP and followed by the barn designated for CLHP. All birds were taught how to drink water from nipple waters and provided feed and water on an *ad libitum* basis. The study was conducted as a 2x2x2 factorial arrangement of breed (Cobb-500; Ross-308) x recommend production environment (LRLP; CLHP) x sex (male; female). With this approach both breeds were examined under their breeder recommended production environment and also the production recommendations of the other breeder. The performance study was conducted in three phases, starter, grower, and finisher phases, with starter from day 1 to day 13, grower day 14 to 27 and finisher day 28 to 41 where each phase change consisted of a diet change.

1. Cobb male in LRLP production system
2. Cobb female in LRLP production system
3. Ross male in LRLP production system
4. Ross female in LRLP production system
5. Cobb male in CLHP production system
6. Cobb female in CLHP production system
7. Ross male in CLHP production system
8. Ross female in CLHP production system

Individual bird data was recorded according to the wing band number and pen number. On days 7, 13, 20, 27, 34, and 41 all birds were individually weighed along with pen feeders and recorded. Feed consumption was calculated by the amount of feed offered minus the amount of feed leftover at the time the birds were individually weighed. A representative sample of the starter, grower, and finisher rations was taken and was analyzed for gross energy, carbon, and nitrogen content. Finally, on these days two birds were randomly selected from each pen to be utilized in the 40 metabolic chambers for the carbon balance study.

Carbon Balance Study

Forty metabolic chambers were housed in two environmentally controlled separate rooms. Each room had 20 chambers, 12 broiler chambers (28.6 X 37.4 X 44) and 8 turkey chambers (46 X 63.8 X 66). One room was designated to simulate the LRLP environment while the other was to simulate the CLHP. Treatments remained the same as in the performance study however only with 5 replications. Once the birds were randomly selected from each pen they were all transferred and placed in the chambers.

A day before birds were placed in the chambers, the air compressor and data acquisition system was turned on and checked for proper functioning. Oxygen flow rate was set based on body weight. To calibrate the analyzers, a known concentration of oxygen and carbon dioxide were read by the analyzer and adjusted accordingly.

On day 7 and 13, two birds were placed in broiler chambers and four birds were placed in turkey metabolic chambers. On day 20, two birds were placed in the smaller metabolic chamber and three birds placed in the larger metabolic chamber. On day 27 and 34 one bird was placed in the smaller metabolic chamber and two birds were placed in the larger metabolic chamber (Table 4). The starter, grower, and finisher phases were each represented with each bird being removed from the chamber and individually weighed. Feed consumption was calculated by the amount of feed offered minus the amount of feed leftover at the time the birds were individually weighed. Birds placed in the metabolic chambers on day 7 were removed on day 11 to represent the starter phase. For the grower phase, birds were placed in the metabolic chambers on day 13 and on day 20, and removed on day 19 and day 24. Finisher phase birds placed in the metabolic chambers on day 27 and 34 were removed on days 32 and 39.

Gas data was continuously collected. Oxygen consumption and carbon dioxide produced were measured in each chamber for one minute (3 times an hour) and recorded by the acquisition system. Collection lines were checked daily and any problems were addressed. These values were regressed against time. The gas exchange estimates were used to estimate heat production according to the Brouwer (1965) equation, where heat produced=16.18 x O_2 consumed + 5.02 x CO_2 produced.

At the completion of each phase in both experiments, body composition was measured, partially using Dexa x-ray densitometer (Dixson, 2001; McKinney and Teeter, 2004) and body weight based equation developed by this lab due to accidental destruction of our Dexa x-ray during the analysis. The body weight (bwt) equations (Dixon, 2001; McKinney and Teeter, 2004) used were:

Bird Protein (g per bird) = $(-0.82173 + (0.16142*\text{bwt}) + (0.00001365*\text{bwt}^2) + (-2.82793\text{E-}9*\text{bwt}^3))$

Bird Fat (g per bird)= $(-0.12859 + (0.07676*\text{bwt}) + (0.00004223*\text{bwt}^2) + (-3.35167\text{E-}9*\text{bwt}^3))$

Bird Water (g per bird) = (2.06933 + (0.73310*bwt) + (-0.00005838*bwt^2) + (5.984265E-9*bwt^3))

Once these numbers were calculated the following calculations were used, also developed by this lab:

Protein balance

Cumulative protein consumption (g per bird) = cumulative feed consumption (g, per bird) x amount of protein in diet (g per bird)

Protein efficiency (%) = bird protein (g per bird)/cumulative protein consumption (g per bird) x 100

Energy balance

Cumulative metabolizable energy intake (kcal/g per bird) = cumulative metabolizable energy(kcal/g) of diet x cumulative feed consumption

Carcass energy retention (kcal/g per bird) = (bird protein (g, per bird) x 5.65) + (bird fat (g, per bird) x 9.3)

Net energetic efficiency (%) = carcass energy retention (kcal/g, per bird)/cumulative metabolizable energy intake (kcal/g per bird)

Nitrogen balance

Cumulative nitrogen intake (g per bird) = Cumulative feed intake (g) x nitrogen content in diet

Nitrogen retention (g per bird) = Bird carcass protein (g per bird)/6.25

Nitrogen excreted (g per bird) = cumulative Nitrogen intake (g per bird)-Nitrogen retention (g per bird)

Nitrogen efficiency (%) = Cumulative nitrogen intake (g per bird)- Nitrogen excreted (g per bird) x 100

Carbon Balance

Heat production (kcal/g per bird) = Cumulative energy intake (kcals/g, per bird) – Carcass energy retention (kcal/g per bird)

Cumulative carbon consumption (g per bird) = Cumulative feed intake (g per bird) x % carbon in diet

Carbon retention (g per bird) = (carcass protein (g per bird) x 0.5296) + (carcass fat (g per bird) x 0.72)

Heat production in kj = heat production (kcal/g per bird) x 4.184 (specific heat of water)

CO_2in Liters = heat production in kj/21.53

CO_2in moles = CO_2 in liters/22.4(moles)

CO_2 in grams = CO_2 in moles x 44

Gaseous Carbon (g per bird) = CO_2 in grams x 0.2727

Carbon excreted (g per bird) = Cumulative Carbon intake (g per bird) - Carbon retention (g per bird) x 100

Percent Carbon in gas produced (%) = Gaseous carbon (g per bird)/cumulative carbon consumption (g per bird) x 100

Percent Carbon in excreta (%) = gaseous carbon (g per bird)/cumulative carbon consumption (g per bird) x 100

Percent carbon retention (%) = Carbon retention (g per bird)/ Cumulative carbon consumption (g per bird) x 100

The experiment was a 2 x 2 x 2 factorial arrangement where main effects of environment, breed, and sex were analyzed using the General Linear Models procedure of SAS (2000), with the probability values $P<0.05$ considered significant. When a significant F-statistic was detected, least square means was used for treatment comparisons.

RESULTS

Performance

The experiment was successfully conducted for the starter, grower and finisher phases. Upon successful completion of the experiment, results were analyzed as described. Results can be viewed in Tables 5-8. As no interactions were noted among breed, sex, and environment, only the main effects of treatment are presented for each age.

As expected, live bird weight increased (P<0.05) with bird age (Table 5) environmental differences were noted (P<0.05) between the treatments during the starter period (days 7 and 13) and grower period (days 20 and 27). Birds under the CLHP treatment had greater (P<0.05) body weight. During the grower phase (days 20 and 27) CLHP birds were (P<0.05) heavier compared to LRLP birds. However, during the finisher phase there was no difference (P>0.10) between environments.

Investigating the breed effects indicated a difference (P<0.05) between Cobb and Ross breeds only during the starter phase (days 7 and 13). During this phase, Ross birds were heavier (P<0.05) compared to Cobb birds. Finally, as anticipated, male birds weighed more than females throughout the experiment (P<0.05).

Data analysis in Table 6 examines the cumulative feed consumption, grams per bird, through all growth phases. Through the starter (days 0-7 and 0-13) and half of the grower phase (days 0-20 only), environment expressed effects on feed consumption between the two treatments, with treatment CLHP consuming more (P<0.05) feed than treatment LRLP. Progressing to the breed effects, the Ross birds consumed 5% more (P<0.05) feed on days 0-13, 0-20 and 0-27. Lastly, as expected, male birds consumed more (P<0.05) feed throughout the experiment.

Weekly body weight gain results (Table 7) indicated a (P<0.05) difference between the two environments from the starter phase to the finisher phase. On days 0-7, 8-13, and 14-20, CLHP birds gained more (P<0.05) weight compared to LRLP. However, on days 21-27, and 28-34, LRLP gained more ($P<0.05$). As far as the breed effect, Ross birds gained more ($P<0.05$) than Cobb birds only during the starter phase (days 0-7 and 8-13). As expected, males gained more ($P<0.05$) weight than females throughout the experiment. Finally, cumulative body weight gain (day 0-41) sex was only significant with male birds weighing more ($P<0.05$) than female birds.

Cumulative feed conversion ratio (FCR) increased ($P<0.05$) as the birds aged (Table 8). Throughout the experiment, environment had little effect on FCR ($P<0.05$); however, FCR for CLHP birds was numerically lower. As far as breed effects, only a difference ($P<0.05$) on day 0-34 with Cobb birds having a lower ($P<0.05$) FCR was noted. Sex was only significant at the end of the grower period (day 0-34) with male birds being more ($P<0.05$) efficient than female birds.

Cumulative protein intake increased ($P<0.05$) as birds aged (Table 9). There was no interaction between environment, breed, and sex ($P>0.10$); therefore main effects of environment, breed and sex were evaluated (Table 9). Throughout the experiment, environmental effects indicated differences between LRLP and CLHP environments, with CLHP birds consuming more ($P<0.05$) protein than LRLP birds on days 7, 13, 20, 27, and 34. Furthermore, breed indicated a difference ($P<0.05$) on days 13, 20, and 27 with Ross birds consuming more ($P<0.05$) protein than Cobb birds. Lastly, as expected, male birds consumed more ($P<0.05$) protein compared to female birds throughout the experiment.

There were no interaction, among environment, breed, and sex; however, environment exposed significant differences (Table 10) in grams of carcass protein.

CLHP birds contained more ($P<0.05$) protein on day 7, 13, 20, and 22 than LRLP birds. Similarly, there was a difference between the two strains, with Ross birds containing more ($P<0.05$) protein on days 7 and 13 than Cobb birds. Apart from the younger bird, carcass protein on day 41 Cobb birds contained more, although only numerical ($P=0.67$), protein at 485 g versus the Ross breed birds containing 479 g. As expected, male birds contained 12% more ($P<0.05$) grams of protein than female birds.

Environmental effects on cumulative carcass protein gain (Table 11) indicated birds in environment CLHP gained more ($P<0.05$) grams of protein on days 0-7, 0-13, and 0-20 than LRLP for a 16% average difference on these days. During the starter phase (days 0-7 and 0-13) Ross birds gained more grams of protein ($P<0.05$) than Cobb birds. However, for days 0-41, Ross and Cobb birds were similar ($P>0.10$). Lastly, male birds gained more ($P<0.05$) grams of protein than female birds.

Cumulative protein efficiency (%) decreased as birds aged ($P<0.05$). There was no interaction between environment, breed and sex ($P>0.10$); thus main effects of environment, breed and sex were considered (Table 12). Throughout the experiment, LRLP had a higher ($P<0.05$) protein efficiency (%) when compared to CLHP birds. On days 0-34, Cobb birds had greater ($P<0.05$) efficiencies then Ross birds. Lastly, on days 27 and 34, males had greater ($P<0.05$) protein efficiency than females.

Carcass fat during the starter and grower phases (Table 13) increased for birds exposed to the CLHP environment than LRLP, uncovering a 19% difference at the end of the starter period. Furthermore, although only numerical, LRLP birds had 3 grams more carcass fat than CLHP birds. Similarly, Ross birds contained more ($P<0.05$) grams of carcass fat than Cobb birds. Additionally on day 41, Cobb birds contained 6 grams more than Ross birds for a numerical difference. Lastly, male birds contained more ($P<0.05$) carcass fat than female birds throughout the experiment.

Results of cumulative fat gain can be reviewed in Table 14. CLHP birds gained more ($P<0.05$) grams of carcass fat than LRLP birds (Days 0-7, 0-13, 0-20, and 0-27), with an average of 14% more protein ($P<0.05$) in CLHP birds ($P>0.10$). Ross breed birds gained more ($P<0.05$) grams of fat than Cobb birds (days 0-7 and 0-13) for a 9% difference ($P>0.10$). As expected, male birds gained more ($P<0.05$) grams of carcass fat throughout the experiment than females.

Cumulative metabolizable energy (ME) consumption was calculated by multiplying the cumulative feed consumption by the ME content of the diet. Cumulative metabolizable energy intake increased with bird age. There was no interaction ($P>0.10$) among environment, breed and sex; therefore main effects of environment, breed, and sex were evaluated (Table 15). On days 0-7, 0-13, 0-20, and 0-27, CLHP birds consumed more ($P<0.05$) metabolizable (kcals/gram) energy than LRLP birds. However, on days 34 and 41, effects disappeared. On 0-13, 0-20, and 0-27, Ross birds consumed more ($P<0.05$) metabolizable (kcals/gram) energy compared to Cobb birds. As expected, male birds consumed more ($P<0.05$) energy (kcals/gram) than females.

The carcass retained energy was calculated using the carcass protein and carcass fat from the composition of the birds. Both carcass protein and carcass fat were multiplied by their respective energy values of 5.65 kcal/gram and 9.3 kcal/gram. Those values were added to quantify the energy retained (kcal/gram) as tissue in the birds.

Retained energy was calculated by first calculating fat energy and protein energy, then adding them together to get the amount of energy retained. There was no significant interaction among environment, breed, and sex; therefore, main effects were considered (Table 16). CLHP birds retained more ($P<0.05$) energy on days 7, 13, 20, and 27 than LRLP birds. Ross birds retained more ($P<0.05$) energy on days 7 and 13 than Cobb birds. Male birds retained more energy than female birds throughout the experiment. However, on day 41 environment and breed effects disappeared.

Energy efficiency (%) decreased as birds aged (Table 17). On day 34, Cobb birds indicated a higher ($P<0.05$) energetic efficiency (%) over the Ross birds. Furthermore, days 27, 34 and 41, males had a higher efficiency (%). Lastly, day 41 environment and breed effects disappeared and showed no differences.

Data analysis in Table 18 examines the cumulative nitrogen intake, through all growth phases. The starter and grower phases showed CLHP birds consumed more ($P<0.05$) nitrogen than LRLP birds due to CLHP diet containing more protein than LRLP diet. Ross birds consumed an average of 5% more ($P<0.05$) grams of nitrogen on days 0-13, 0-20 and 0-27. Lastly, as expected, male birds consumed more ($P<0.05$) grams of nitrogen than female birds throughout the experiment.

Interaction among environment, breed, and sex, was similar for grams of carcass nitrogen (Table 19). CLHP birds contained more ($P<0.05$) grams of nitrogen days 7, 13, 20, and 27, than LRLP birds. Ross birds contained more grams of nitrogen compared to the Cobb birds on days 7 and 13. Males had more ($P<0.05$) carcass nitrogen than female birds. Again, on day 41 environment and breed effects disappeared.

Grams of nitrogen excreted was calculated and shown in Table 20. Here, CLHP birds excreted 50% more (P<0.05) nitrogen during the starter phase (days 0 and 13), 37% more in the grower phase (day 20 and 27) and 21% more in the finisher phase than LRLP birds. This is due to the higher protein content of the CLHP treatment. Breed effects were only significant on days 20, 27, and 34. Here, the Ross birds excreted more nitrogen (P<0.05) than Cobb birds. Male and female birds showed no differences throughout the experiment.

Nitrogen efficiency was calculated using the grams of cumulative nitrogen intake minus the nitrogen excreted and expressed as a percentage. Here, LRLP birds were more (P<0.05) nitrogen efficient than the CLHP birds throughout the experiment. Breed effects were only observed on day 34 with Cobb birds more (P<0.05) efficient than Ross birds. As expected, throughout the experiment, male birds were more (P<0.05) efficient than female birds on days 27 and 34.

CLHP environment birds produced more (P<0.05) heat than LRLP birds (Table 22). For example, on day 20, CLHP produced 1,524 kcals per gram per bird versus the LRLP producing 1,331 kcals per gram per bird for a 13% difference (P<0.05). Ross birds produced more (P<0.05) heat than the Cobb birds on days 13, 20, 27, and 34. Furthermore, although only numerical, on day 41 Cobb breed birds still produced less (P>0.10) heat.

Following composition calculations, bird protein and fat were related to carbon, then expressed as carbon retention. Cumulative carbon consumption was also calculated and is shown in Table 23.

There were no interaction among environment, breed, and sex; therefore, the main effects of environment, breed, and sex were evaluated (Table 23). On days 0-7, 0-13, and 0-20, CLHP treatment consumed more ($P<0.05$) carbon than LRLP birds. Ross birds consumed more ($P<0.05$) grams of carbon regardless of environment on days 0-13, 0-20, and 0-27. Finally, male birds consumed more ($P<0.05$) grams carbon than female birds.

On days 7, 13, 20, and 27 CLHP birds retained more ($P<0.05$) grams of carbon (Table 24) than LRLP birds. However, on day 41, although only numerical, LRLP retained more ($P>0.10$) grams of carbon than CLHP birds. Moving onto breed effects, Ross birds retained more ($P<0.05$) grams of carbon on days 7 and 13. However, on day 41, Cobb birds retained 1% more ($P>0.10$) grams of carbon than Ross birds. Lastly, male birds retained more ($P<0.05$) grams of carbon than female birds.

On days 7, 13, and 20, with CLHP birds produced more ($P<0.05$) grams of gaseous carbon versus the LRLP birds (Table 25). However by day 41, there were no differences between CLHP and LRLP ($P>0.10$) grams of gaseous carbon ($P>0.10$). Ross birds produced more ($P<0.05$) grams of gaseous carbon on days 20, 27 and 34 than Cobb birds.

As birds aged, the amount of carbon excreted increased ($P<0.05$) (Table 26). On days 7,13, and 20, CLHP birds excreted more ($P<0.05$) grams of carbon, for example on day 20, CLHP excreted 128 grams of carbon, while the LRLP birds excreted 113 grams, for a 12 percent difference ($P<0.05$). Furthermore, Ross birds excreted more ($P<0.05$) grams of carbon regardless of environment on days 7, 13, 20, and 27. Finally, males excreted more ($P<0.05$) grams of carbon throughout the experiment.

Percent of carbon in the gas produced was affected by environment (Table 27). The CLHP birds released an average of 6% lower ($P<0.05$) percentage of carbon gas than the LRLP birds on day 7 and day 13. Ross birds had a higher ($P<0.05$) percent of carbon in the gas, a 2% difference. Finally, males released a higher ($P<0.05$) percentage of carbon gas than females on days 27, 34, and 41.

Results in Table 28 presents the differences in the percent carbon contained in the excreta. Here an environmental difference ($P<0.05$) is observed throughout the experiment. CLHP birds had higher percent of carbon in the excreta, except on day 20 and 27 due to diet. On days 20 and 27, higher ($P<0.05$) percent carbon excreta were that of the LRLP. On day 34, Cobb birds excreted 1% more ($P<0.05$) carbon. Lastly, male birds had a 1% higher ($P<0.05$) percent carbon in excreta on days 20, 27, 34, and 41.

As birds aged, the percent of carbon retained decreased ($P<0.05$, Table 29). There was no interactions among environment, breed, and sex; therefore main effects were investigated. On days 7, LRLP birds retained more ($P<0.05$) carbon (%); however on day 20, CLHP birds retained 3% more ($P<0.05$) than LRLP birds. Cobb birds retained more ($P<0.05$) than Ross birds (35% vs. 34%) on day 34. On days 27, 34, and 41, males retaining more ($P<0.05$) carbon.

Overall on day 41 there were little differences between environment and breed. CLHP birds had less ($P>0.10$) percent carbon in gas and more ($P>0.10$) percent carbon retained, but LRLP birds had less ($P>0.10$) percent carbon in the feces. Furthermore, both LRLP, CLHP, Cobb and Ross birds were similar in performance (body weight, cumulative feed consumption, body weight gain, and FCR), and similar for carcass characteristics (protein, fat, energy, carbon).

DISCUSSION

Environmental characteristics such as continuous lighting, 23 hours light; 1 hour dark, versus an intermittent lighting program revealed differences through the starter and grower phases with the continuous lighting birds weighing (g, per bird) gaining (g, per bird) and consuming more (g, per bird); however, during the finisher phase intermittent lighting birds (LRLP) weighed, gained, and consumed more feed than the continuous lighting birds (CLHP). This same response has been thoroughly noted and agrees with other published research (Rahimi et. al, 2005; Petek et. al, 2005; Ohtani and Leeson, 2005). These results are likely attributable to diet composition and the lighting program of the LRLP treatment. Diets formulated to LRLP (Table 3) and CLHP (Table 4) standards, CLHP environment rations contain a higher amount of protein versus the LRLP rations, causing the CLHP birds to be heavier ($P<0.05$) in body weight until day 41. The high amount of feed consumption is most likely due to the non-light restricted program that CLHP environment employs. However, it is important to note at the beginning of the finisher phase (day 34) there is no longer a significant difference between the two environments and two breeds. By day 41, Cobb breed and LRLP environment has become equal or surpasses that of the CLHP environment.

Feed conversion ratio (FCR) was lower for birds under CLHP environment which disagrees with Ohtani and Leeson (2000) and Rahimi et. al (2005). Diet composition can be attributed to this difference. Differing diets, high protein fed to continuous lighting treatment and low protein diet fed to intermittent light (LRLP) can play a role, along with lysine levels. Rahimi et. al (2005) diet contained lower percentage of lysine that was fed to all birds while in this experiment the CLHP birds were fed higher lysine than LRLP birds.

With regards to measured carcass characteristics for protein and fat revealed constant lighting (CLHP) contained more carcass protein until day 41. On day 41, light restriction birds (LRLP) contained more protein which has also been reported by Lein et. al, 2007. In this study constant lighting treatment contained more whole breast, fillet, and tender (Lein et. al, 2007). Cumulative metabolizable energy (ME) intake (kcal/g, per bird), and carcass energy retention (kcal/g, per bird) was also higher in the early stages of the experiment for continuous lighting birds (Ohtani and Leeson, 2000, Apeldoorn et. al, 1999). Assumptions can be made that intermittent lighting (LRLP) birds had improved weight and feed consumption because of the short meal feeding period, followed by a longer period for digesting the meal (Petek et. al, 2005). Furthermore, the LRLP birds have less activity during the dark period compared to the CLHP birds.

Lighting effects also revealed more heat (kcals/g, per bird) was produced from CLHP birds until day 41, where LRLP produced more heat. However, Ohtani and Leeson (2000) and Apeldoorn et. al (1999) reported intermittent lighting (LRLP) birds had higher heat production throughout a six week experiment. It is well documented that heat production is dependent on environmental temperature in chickens (Farrel and Swain, 1977; Yunianto et al., 1997). So, with CLHP birds the lights can give off heat causing a higher heat production.

Diet composition played a major role in environmental effects. The higher protein diet birds weighed more, consumed more feed, and had a more efficient FCR for the starter and grower phases which is consistent with Smith and Pesti (1998), Li et. al (2010), and Ferguson et. al (1998). Conclusions drawn from this are that protein requirements for minimum feed conversion are greater than that for weight gain (Ferguson et. al, 1998). Carcass protein results showed high protein diet birds (CLHP) contained more grams of protein until day 41, where LRLP had higher protein. Carcass fat indicated these same results. In a study done by Bregendahl et. al (2002), birds fed low protein diets also consumed more feed and utilized the feed less efficiently, and also retained more protein and less fat, which is comparable to this experiment. It has been suggested that lysine levels can contribute to breast meat yield (Razaei et. al, 2004). Several studies have shown that additional lysine levels increase breast meat accretion (Acar et. al, 1991; Moran and Bilgili, 1990; Gorman and Balnave, 1995; Han and Baker, 1991). Again, the CLHP birds diet contained higher levels of lysine and more protein than the LRLP birds.

Results, with respects to breed effects, on growth performance indicate that Ross birds had a lower bodyweight (g), until day 27, than the as hatched weights in the Ross broiler performance guide (2012, Appendix Table 1). After day 27 Ross birds exceeded expected weights. The same can be said for the Cobb birds, which also had lower bodyweight (g), until day 27, than the Cobb broiler performance supplement (2012, Appendix Table 2). Furthermore, both breeds (Cobb and Ross) consumed less than their respective performance guide (Cobb, 2012; Ross, 2012), making for a decrease in the birds FCR. This could be due to the difference in commercial environments versus an experimental environment. During this experiment, birds were fed *ad libitum* while in commercial settings birds are on a limited feeding program. On an *ad libitum* feeding programs birds can eat whenever they would like, in commercial feeding program feed is only offered certain times and for only a certain amount of time. Commercial feeding keeps the birds on a tighter feeding regime to increase intake and decrease bird activity. Furthermore in this experimental setting the birds were handled each week to obtain their weight, which added stress to the birds.

Extending the discussion of breed effects, measured carcass characteristics indicated Ross birds contained more grams of fat until day 41. For carcass fat, again Ross birds contained more grams of fat until day 41. When comparing carcass characteristic's to breed standards as set by Cobb-Vantress and Aviagen (Ross birds) in their respective breeder performance objectives (2012), both Ross and Cobb birds contained less carcass protein (Appendix Table 3, Appendix Table 4).

In a study conducted by Hogmin et. al, (2011) reported an average carcass carbon as 544 grams, this is in compliance with the experiment conducted which was 585 grams. Assumptions could be made the increase in genetic lines of birds has increased there efficiency to accumulate more protein, fat and therefore carbon than in previous studies (Hogmin et. al, 2011, Zervas, 2011).

The results suggests that gaseous carbon increased as birds aged which is in agreement with Burns et. al (2009) which found as the birds grew bigger gaseous carbon increased. Burns et. al. (2009) study was conducted over a whole year while this experiment was conducted only for 41 days. During the colder months brooders and heaters are used to heat the facilities which can add to the carbon emissions during those months, however during the warm months ventilation is provided by fans on a intermittent schedule, lowering the carbon emissions by fans during these months (Burns et. al, 2009).

A reduction in carbon dioxide released from the poultry industry might be advantageous in that it contributes positively to the reduction in greenhouse gasses. Furthermore retention of carbon in body tissue instead of loss to the atmosphere increases biological efficiency of the birds in addition to the economic benefits that may be attained.

TABLE 1. Composition of diets used for broilers under LRLP treatment

	Age interval		
Ingredient, %	Starter	Grower	Finisher
Corn	52.82	57.12	60.41
Soybean meal	39.66	34.85	30.71
Soybean oil	3.45	4.20	5.17
Dicalcium phosphate	2.04	1.81	1.68
Limestone	1.06	0.97	0.95
Salt	0.48	0.48	0.43
DL-methionine	0.16	0.22	0.20
Monteban	0.08	0.08	0.08
Mineral pre-mix	0.75	0.08	0.08
Choline chloride	0.07	0.07	0.07
Threonine 98%	0.05	0.07	0.11
Vitamin pre-mix	0.04	0.04	0.04
L-Lysine HCL	0.00	0.00	0.07
	Calculated Values		
ME (Kcal/kg)	2,990	3,085	3,180
CP, %	21.30	21.30	19.1
Arg, %	1.50	1.35	1.22
Lys, %	1.28	1.15	1.09
Met,%	0.50	0.53	0.49
Ca, %	1.00	0.90	0.85
Carbon, %	38.55	41.70	41.70
Nitrogen, %	3.41	3.43	3.05

TABLE 2. Cobb[1] lighting program used

Age (days)	Hours dark
1	1
5-21	12
22	11
23	10
24	9
29	8
30	7
31-36	6
37	5
38	4
39	3
40	2
41	1

[1] Ross lighting program was 23 hours light; 1 hour dark

TABLE 3. Composition of diets used for broilers under CLHP treatment

	Age interval		
Ingredient, %	Starter	Grower	Finisher
Corn	45.78	48.17	53.63
Soybean meal	44.89	41.41	36.34
Soybean oil	5.27	6.77	6.61
Dicalcium phosphate	2.01	1.77	1.65
Limestone	1.03	0.94	0.93
Salt	0.48	0.48	0.43
DL-methionine	0.26	0.19	0.18
Monteban	0.08	0.08	0.08
Mineral pre-mix	0.08	0.08	0.08
Choline chloride	0.05	0.05	0.05
Threonine 98%	0.02	0.00	0.00
Vitamin pre-mix	0.04	0.04	0.04
	Calculated Values		
ME (Kcal/kg)	3,029	3,154	3,205
CP,%	26.19	25.48	21.52
Arg, %	1.65	1.54	1.39
Lys, %	1.42	1.33	1.19
Met,%	0.62	0.54	0.50
Ca, %	1.00	0.90	0.50
Carbon, %	40.80	42.00	42.15
Nitrogen, %	4.19	4.08	3.44

TABLE 4. Number of birds placed in chambers

Age (d)	Broiler Chamber[a]	Turkey Chamber[b]
7	2	4
13	2	4
20	2	3
27	1	2
34	1	2

[a]Size of chamber 13''X 17''X 20''
[b]Size of chamber 21''X 29''X 30''

TABLE 5. Live body weight by treatment, g

	Age (d)					
	7	13	20	27	34	41
Environment[1]						
LRLP	155	327	740	1,388	2,128	2,734
CLHP	172	392	874	1,467	2,141	2,724
Breed						
Cobb	159	348	794	1,408	2,127	2,744
Ross	168	371	820	1,447	2,142	2,714
Sex						
Female	159	347	769	1,346	2,002	2,500
Male	168	371	845	1,509	2,268	2,958
	Probabilities					
Environment	<.0001	<.0001	<.0001	0.0056	0.7796	0.9041
Breed	0.0096	0.0016	0.1102	0.1578	0.7583	0.7202
Sex	0.0106	0.0008	<.0001	<.0001	<.0001	<.0001
Environment*Breed	0.0547	0.1274	0.3161	0.8740	0.9332	0.0952
Sex*Environment	0.8779	0.3513	0.7192	0.8506	0.7490	0.8777
Sex*Breed	0.5899	0.3159	0.7758	0.7251	0.6393	0.2385
Sex*Environment*Breed	0.4986	0.7617	0.9475	0.9729	0.5269	0.2315

[1]LRLP=Light Restriction, Low Protein; CLHP=Constant Light, High Protein.
[2]Least square means for main effects of environment, breed, and sex is 36 reps per treatment.

TABLE 6. Cumulative feed consumption by treatment, g per bird

	Age (d)					
	0-7	0-13	0-20	0-27	0-34	0-41
Environment[1]						
LRLP	131	367	897	1,810	3,007	4,348
CLHP	145	431	1,037	1,867	2,963	4,191
Breed						
Cobb	135	387	942	1,786	2,919	4,268
Ross	141	411	992	1,891	3,052	4,271
Sex						
Female	134	387	928	1,760	2,871	3,981
Male	142	411	1,006	1,917	3,100	4,558
Probabilities						
Environment	0.0001	<.0001	<.0001	0.1334	0.5121	0.3869
Breed	0.0821	0.0027	0.0065	0.0061	0.0528	0.9841
Sex	0.0279	0.0032	<.0001	<.0001	0.0011	0.0048
Environment*Breed	0.1302	0.2984	0.2799	0.8290	0.9778	0.8253
Sex*Environment	0.9917	0.6257	0.6479	0.6929	0.9838	0.7937
Sex*Breed	0.2645	0.7152	0.4468	0.5106	0.6073	0.8136
Sex*Environment* Breed	0.4111	0.6689	0.3331	0.6532	0.7338	0.5209

[1] LRLP=Light Restriction, Low Protein; CLHP=Constant Light, High Protein.

[2] Least square means for main effects of environment, breed, and sex is 36 reps per treatment.

TABLE 7. Bodyweight gain by treatment, g per bird

	Age (d)						
	0-7	8-13	14-20	21-27	28-34	34-41	0-41
Environment[1]							
LRLP	112	172	418	639	728	657	2,691
CLHP	130	220	479	581	671	578	2,681
Breed							
Cobb	117	189	446	612	715	618	2,702
Ross	125	202	451	609	685	618	2,671
Sex							
Female	117	188	423	564	642	541	2,457
Male	125	204	473	657	757	694	2,915
	Probablities						
Environment	<.0001	<.0001	<.0001	<.0001	0.0140	0.2610	0.9053
Breed	0.0246	0.0027	0.7009	0.8338	0.1862	0.9969	0.7066
Sex	0.0113	0.0005	<.0001	<.0001	<.0001	0.0380	<.0001
Environment*Breed	0.0716	0.2241	0.6076	0.1677	0.8408	0.4997	0.9038
Sex*Environment	0.8109	0.1378	0.8444	0.4644	0.3468	0.7528	0.8741
Sex*Breed	0.5489	0.0687	0.9781	0.9359	0.2715	0.5292	0.2394
Sex*Environment* Breed	0.5618	0.8461	0.7250	0.6023	0.4353	0.6668	0.2300

[1] LRLP=Light Restriction, Low Protein; CLHP=Constant Light, High Protein.

[2] Least square means for main effects of environment, breed, and sex is 36 reps per treatment.

TABLE 8. Cumulative feed conversion ratio (FCR)[2] by treatment

	Age (d)					
	0-7	0-13	0-20	0-27	0-34	0-41
Environment[1]						
LRLP	0.844	1.124	1.213	1.306	1.418	1.585
CLHP	0.837	1.102	1.190	1.276	1.395	1.534
Breed						
Cobb	0.844	1.114	1.189	1.271	1.381	1.552
Ross	0.837	1.112	1.214	1.310	1.432	1.567
Sex						
Female	0.838	1.116	1.208	1.308	1.434	1.591
Male	0.843	1.110	1.195	1.273	1.378	1.528
Probabilities						
Environment	0.4270	0.1430	0.2009	0.1415	0.1370	0.1109
Breed	0.4214	0.8913	0.1575	0.0548	0.0014	0.6374
Sex	0.6467	0.6810	0.4563	0.0965	0.0005	0.0509
Environment*Breed	0.9745	0.4457	0.9658	0.9221	0.5368	0.2767
Sex*Environment	0.9514	0.5266	0.6882	0.3264	0.3481	0.4191
Sex*Breed	0.0821	0.3634	0.5535	0.6605	0.4960	0.1257
Sex*Environment* Breed	0.4111	0.6689	0.3331	0.6532	0.7338	0.5209

[1] LRLP=Light Restriction, Low Protein; CLHP=Constant Light, High Protein.

[2] Calculated as cumulative feed consumption/live body weight.

[3] Least square means for main effects of environment, breed, and sex is 36 reps per treatment.

TABLE 9. Cumulative protein intake by treatment, g per bird

	Age (d)					
	0-7	0-13	0-20	0-27	0-34	0-41
Environment[1]						
LRLP	28	78	191	386	574	830
CLHP	38	113	272	489	637	901
Breed						
Cobb	32	93	225	425	592	866
Ross	34	99	237	450	619	866
Sex						
Female	32	93	222	418	582	808
Male	34	98	241	456	628	924
Probabilities						
Environment	<.0001	<.0001	<.0001	<.0001	<.0001	0.0587
Breed	0.0691	0.0027	0.0043	0.0071	0.0658	0.9944
Sex	0.0343	0.0036	<.0001	<.0001	0.0014	0.0040
Environment*Breed	0.1043	0.1894	0.1677	0.9408	0.9191	0.8208
Sex*Environment	0.9186	0.5842	0.3569	0.4109	0.8794	0.9414
Sex*Breed	0.2936	0.6848	0.4042	0.5390	0.5814	0.7911
Sex*Environment*Breed	0.9186	0.5843	0.4769	0.7692	0.4280	0.7026

[1] LRLP=Light Restriction, Low Protein; CLHP=Constant Light, High Protein

[2] Least square means for main effects of environment, breed, and sex is 36 reps per treatment.

TABLE 10. Carcass protein by dietary treatment, g per bird

	Age (d)					
	7	13	20	27	34	41
Environment[1]						
LRLP	24	53	125	242	377	483
CLHP	27	64	149	256	379	481
Breed						
Cobb	25	57	135	246	377	485
Ross	27	61	139	253	379	479
Sex						
Female	25	57	130	234	354	443
Male	27	61	144	264	402	522
Probabilities						
Environment	<.0001	<.0001	<.0001	0.0056	0.7869	0.9289
Breed	0.0095	0.0016	0.1083	0.1574	0.7663	0.6668
Sex	0.0105	0.0008	<.0001	<.0001	<.0001	<.0001
Environment*Breed	0.0542	0.1249	0.3144	0.8751	0.9323	0.1018
Sex*Environment	0.8749	0.3437	0.7024	0.8541	0.7399	0.8792
Sex*Breed	0.5920	0.3116	0.7672	0.7213	0.6249	0.2501
Sex*Environment*Breed	0.4980	0.7576	0.9493	0.9720	0.5204	0.2419

[1] LRLP=Light Restriction, Low Protein; CLHP=Constant Light, High Protein.

[2] Least square means for main effects of environment, breed, and sex is 36 reps per treatment.

TABLE 11. Carcass cumulative protein gain by dietary treatment, g per bird

	Age (d)					
	0-7	0-13	0-20	0-27	0-34	0-41
Environment[1]						
LRLP	18	47	119	236	371	477
CLHP	21	58	143	250	373	476
Breed						
Cobb	19	51	129	240	371	479
Ross	21	55	133	247	373	473
Sex						
Female	19	51	124	228	348	437
Male	21	55	138	258	396	516
Probabilities						
Environment	<.0001	<.0001	<.0001	0.7848	0.7848	0.9300
Breed	0.0239	0.0025	0.1241	0.7853	0.7853	0.6543
Sex	0.0111	0.0008	<.0001	<.0001	<.0001	<.0001
Environment*Breed	0.0707	0.1387	0.3259	0.9251	0.9251	0.1005
Sex*Environment	0.8084	0.3208	0.6892	0.7439	0.7439	0.8757
Sex*Breed	0.5519	0.3212	0.7750	0.6221	0.6221	0.2510
Sex*Environment* Breed	0.5599	0.7926	0.9333	0.5159	0.5159	0.2404

[1] LRLP=Light Restriction, Low Protein; CLHP=Constant Light, High Protein.

[2] Least square means for main effects of environment, breed, and sex is 36 reps per treatment.

TABLE 12. Cumulative protein efficiency[2] by treatment, %

	Age (d)					
	0-7	0-13	0-20	0-27	0-34	0-41
Environment[1]						
LRLP	88	68	65	63	66	59
CLHP	73	57	55	53	60	54
Breed						
Cobb	80	63	60	59	64	56
Ross	81	63	60	57	61	56
Sex						
Female	81	62	60	57	61	55
Male	80	63	61	59	64	57
Probabilities						
Environment	<.0001	<.0001	<.0001	<.0001	<.0001	0.0003
Breed	0.3627	0.8918	0.1781	0.0585	0.0030	0.6591
Sex	0.7462	0.4926	0.1612	0.0320	0.0002	0.0781
Environment*Breed	0.9799	0.5585	0.6747	0.7433	0.9540	0.3365
Sex*Environment	0.9693	0.5216	0.7278	0.2496	0.2754	0.4968
Sex*Breed	0.0829	0.2870	0.6553	0.5685	0.8778	0.1386
Sex*Environment*Breed	0.4643	0.5606	0.4165	0.6064	0.8848	0.4932

[1] LRLP=Light Restriction, Low Protein; CLHP=Constant Light, High Protein.

[2] Calculated=carcass protein/cumulative protein consumption.

[3] Least square means for main effects of environment, breed, and sex is 36 reps per treatment.

TABLE 13. Carcass fat by dietary treatment, g per bird

	Age (d)					
	7	13	20	27	34	41
Environment[1]						
LRLP	13	29	79	179	323	459
CLHP	14	36	97	193	326	456
Breed						
Cobb	13	32	86	183	323	461
Ross	14	34	90	190	326	455
Sex						
Female	13	32	83	172	296	405
Male	14	34	93	201	353	511
Probabilities						
Environment	<.0001	<.0001	<.0001	0.0056	0.7869	0.9289
Breed	0.0095	0.0016	0.1083	0.1574	0.7663	0.6668
Sex	0.0105	0.0008	<.0001	<.0001	<.0001	<.0001
Environment*Breed	0.0542	0.1249	0.3144	0.8751	0.9323	0.1018
Sex*Environment	0.8749	0.3437	0.7024	0.8541	0.7399	0.8792
Sex*Breed	0.5920	0.3116	0.7672	0.7213	0.6249	0.2501
Sex*Environment* Breed	0.4980	0.7576	0.9493	0.9720	0.5204	0.2419

[1] LRLP=Light Restriction, Low Protein; CLHP=Constant Light, High Protein.

[2] Least square means for main effects of environment, breed, and sex is 36 reps per treatment.

TABLE 14. Cumulative carcass fat gain by dietary treatment, g per bird

	Age (d)					
	0-7	0-13	0-20	0-27	0-34	0-41
Environment[1]						
LRLP	10	26	75	176	320	456
CLHP	11	33	94	190	323	453
Breed						
Cobb	10	28	83	180	320	457
Ross	11	31	87	187	323	452
Sex						
Female	10	28	79	169	293	401
Male	11	31	90	198	350	508
Probabilities						
Environment	<.0001	<.0001	<.0001	0.0054	0.7436	0.8695
Breed	0.0211	0.0021	0.1076	0.1485	0.7448	0.7678
Sex	0.0102	0.0007	<.0001	<.0001	<.0001	<.0001
Environment*Breed	0.0661	0.1243	0.3103	0.9002	0.9329	0.0865
Sex*Environment	0.7953	0.2899	0.6047	0.9372	0.7833	0.8549
Sex*Breed	0.5673	0.2998	0.7248	0.6473	0.6981	0.2293
Sex*Environment*Breed	0.5503	0.7661	0.9540	0.9717	0.5568	0.2213

[1] LRLP=Light Restriction, Low Protein; CLHP=Constant Light, High Protein.

[2] Least square means for main effects of environment, breed, and sex is 36 reps per treatment.

TABLE 15. Cumulative metabolizable energy (ME) intake by treatment, kcal/g per bird

	Age (d)					
	0-7	0-13	0-20	0-27	0-34	41
Environment[1]						
LRLP	391	1,099	2,769	5,587	9,563	13,826
CLHP	438	1,304	3,277	5,887	9,497	13,432
Breed						
Cobb	405	1,165	2,942	5,574	9,318	13,624
Ross	424	1,238	3,097	5,900	9,742	13,635
Sex						
Female	403	1,165	2,897	5,492	9,165	12,709
Male	426	1,238	3,142	5,983	9,895	14,550
Probabilities						
Environment	<.0001	<.0001	<.0001	0.0114	0.7568	0.4932
Breed	0.0811	0.0027	0.0062	0.0062	0.0530	0.9847
Sex	0.0282	0.0032	<.0001	<.0001	0.0012	0.0047
Environment*Breed	0.1283	0.2906	0.2659	0.8531	0.9840	0.8250
Sex*Environment	0.9805	0.6127	0.6131	0.6594	0.9732	0.8031
Sex*Breed	0.2662	0.7132	0.4420	0.5133	0.6055	0.8121
Sex*Environment* Breed	0.8302	0.5967	0.5258	0.7211	0.4379	0.7202

[1] LRLP=Light Restriction, Low Protein; CLHP=Constant Light, High Protein.

[2] Least square means for main effects of environment, breed, and sex is 36 reps per treatment.

TABLE 16. Carcass energy retention[2] by treatments, kcal/g per bird

	Age (d)					
	7	13	20	27	34	41
Environment[1]						
LRLP	257	575	1,438	3,035	5,135	7,002
CLHP	289	701	1,746	3,247	5,178	6,966
Breed						
Cobb	265	615	1,561	3,087	5,133	7,027
Ross	281	660	1,622	3,195	5,179	6,942
Sex						
Female	265	614	1,504	2,922	4,758	6,268
Male	281	662	1,679	3,360	5,555	7,701
Probabilities						
Environment	<.0001	<.0001	<.0001	0.0056	0.7589	0.8876
Breed	0.0093	0.0015	0.1027	0.1483	0.7469	0.7389
Sex	0.0101	0.0007	<.0001	<.0001	<.0001	<.0001
Environment*Breed	0.0531	0.1194	0.3080	0.8944	0.9347	0.0912
Sex*Environment	0.8660	0.3249	0.6513	0.9028	0.7672	0.8633
Sex*Breed	0.5979	0.3019	0.7405	0.6741	0.6734	0.2352
Sex*Environment*Breed	0.4962	0.7479	0.9578	0.9747	0.5454	0.2277

[1] LRLP=Light Restriction, Low Protein; CLHP=Constant Light, High Protein.

[2] Calculated as energy retention=(bird protein x 5.65) + (bird fat x 9.3).

[3] Least square means for main effects of environment, breed, and sex is 36 reps per treatment.

TABLE 17. Net energetic efficiency[2] by treatment, % per bird

	Age (d)					
	7	13	20	27	34	41
Environment[1]						
LRLP	66	52	52	54	54	51
CLHP	66	54	54	55	54	52
Breed						
Cobb	66	53	53	55	55	52
Ross	66	53	52	54	53	51
Sex						
Female	66	53	51	53	52	49
Male	66	53	54	56	56	54
Probabilities						
Environment	0.7281	0.0558	0.0640	0.3794	0.3014	0.2788
Breed	0.3028	0.6492	0.3688	0.1564	0.0155	0.6793
Sex	0.8340	0.3171	0.0544	0.0033	<.0001	0.0029
Environment*Breed	0.8822	0.4930	0.6839	0.9233	0.9086	0.2298
Sex*Environment	0.9805	0.4561	0.9122	0.3802	0.4169	0.4397
Sex*Breed	0.0700	0.3018	0.6793	0.6834	0.7751	0.1617
Sex*Environment* Breed	0.3473	0.6744	0.4511	0.6836	0.9324	0.4003

[1] LRLP=Light Restriction, Low Protein; CLHP=Constant Light, High Protein.

[2] Calculated=carcass energy retention/cumulative energy (ME) consumption.

[3] Least square means for main effects of environment, breed, and sex is 36 reps per treatment.

TABLE 18. Cumulative Nitrogen intake by treatment, g per bird

	Age (d)					
	0-7	0-13	0-20	0-27	0-34	0-41
Environment[1]						
LRLP	4	13	31	62	92	133
CLHP	6	18	42	76	102	144
Breed						
Cobb	5	15	36	67	95	138
Ross	5	16	37	71	99	138
Sex						
Female	5	15	35	66	93	129
Male	5	16	38	72	101	148
			Probabilities			
Environment	<.0001	<.0001	<.0001	<.0001	<.0001	0.0534
Breed	0.0692	0.0027	0.0046	0.0069	0.0566	0.9945
Sex	0.0343	0.0036	<.0001	<.0001	0.0013	0.0040
Environment*Breed	0.1044	0.9101	0.1828	0.9776	0.9291	0.8208
Sex*Environment	0.8174	0.4386	0.3972	0.4505	0.8253	0.9440
Sex*Breed	0.2933	0.6850	0.4106	0.5341	0.5810	0.7908
Sex*Environment* Breed	0.9182	0.5842	0.4853	0.7604	0.4278	0.7023

[1] LRLP=Light Restriction, Low Protein; CLHP=Constant Light, High Protein.

[2] Least square means for main effects of environment, breed, and sex is 36 reps per treatment.

TABLE 19. Carcass Nitrogen[2] by treatment, g per bird

	Age (d)					
	7	13	20	27	34	41
Environment[1]						
LRLP	4	9	20	39	60	77
CLHP	4	10	24	41	61	77
Breed						
Cobb	4	9	22	39	60	78
Ross	4	10	22	40	61	77
Sex						
Female	4	9	21	37	57	71
Male	4	10	23	42	64	83
Probabilities						
Environment	<.0001	<.0001	<.0001	0.006	0.787	0.929
Breed	0.009	0.001	0.108	0.157	0.766	0.667
Sex	0.010	0.001	<.0001	<.0001	<.0001	<.0001
Environment*Breed	0.054	0.125	0.314	0.875	0.932	0.102
Sex*Environment	0.874	0.344	0.702	0.854	0.734	0.879
Sex*Breed	0.592	0.312	0.767	0.721	0.625	0.250
Sex*Environment* Breed	0.498	0.758	0.949	0.972	0.520	0.242

[1] LRLP=Light Restriction, Low Protein; CLHP=Constant Light, High Protein.

[2] Calclulated as bird carcass protein/6.25.

[3] Least square means for main effects of environment, breed, and sex is 36 reps per treatment.

TABLE 20. Nitrogen excreted[2] by treatment, g per bird

	Age (d)					
	7	13	20	27	34	41
Environment[1]						
LRLP	1	4	11	23	31	55
CLHP	2	8	18	35	41	67
Breed						
Cobb	1	6	14	28	34	60
Ross	1	6	15	31	38	61
Sex						
Female	1	6	14	29	36	58
Male	1	6	15	30	36	63
Probabilities						
Environment	<.0001	<.0001	<.0001	<.0001	<.0001	0.002
Breed	0.882	0.179	0.014	0.009	0.003	0.888
Sex	0.385	0.208	0.088	0.243	0.839	0.112
Environment*Breed	0.466	0.586	0.373	0.871	0.801	0.700
Sex*Environment	0.787	0.776	0.415	0.238	0.448	0.739
Sex*Breed	0.138	0.738	0.387	0.566	0.658	0.355
Sex*Environment*Breed	0.456	0.591	0.299	0.695	0.482	0.982

[1] LRLP=Light Restriction, Low Protein; CLHP=Constant Light, High Protein.

[2] Calclulated as cumulative Nitrogen intake – Nitrogen retained.

TABLE 21. Nitrogen efficiency[2] by treatment, %

	Age (d)					
	7	13	20	27	34	41
Environment[1]						
LRLP	88	68	65	62	66	59
CLHP	73	57	56	54	60	54
Breed						
Cobb	80	63	65	59	64	56
Ross	81	63	56	57	62	56
Sex						
Female	81	62	60	57	61	55
Male	80	63	61	59	64	57
Probabilities						
Environment	<.0001	<.0001	<.0001	<.0001	<.0001	0.003
Breed	0.363	0.892	0.183	0.060	0.003	0.660
Sex	0.746	0.492	0.167	0.034	0.002	0.078
Environment*Breed	0.980	0.559	0.693	0.768	0.952	0.337
Sex*Environment	0.969	0.521	0.747	0.267	0.274	0.498
Sex*Breed	0.083	0.287	0.648	0.575	0.878	0.138
Sex*Environment* Breed	0.464	0.561	0.415	0.614	0.885	0.492

[1] LRLP=Light Restriction, Low Protein; CLHP=Constant Light, High Protein.

[2] Calclulated as (cumulative Nitrogen intake – Nitrogen excreted.) / cumulative nitrogen intake x 100.

[3] Least square means for main effects of environment, breed, and sex is 36 reps per treatment.

TABLE 22. Heat production[2] by treatment, kcals/g per bird

	Age (d)					
	7	13	20	27	34	41
Environment[1]						
LRLP	134	524	1,331	2,552	4,429	6,776
CLHP	149	604	1,524	2,641	4,318	6,416
Breed						
Cobb	141	549	1,380	2,487	4,185	6,575
Ross	143	578	1,474	2,641	4,562	6,617
Sex						
Female	138	551	1,393	2,570	4,407	6,427
Male	145	576	1,462	2,623	4,340	6,765
Probabilities						
Environment	0.0063	<.0001	<.0001	0.2901	0.3542	0.2523
Breed	0.6848	0.0739	0.0188	0.0109	0.0022	0.8936
Sex	0.1795	0.1276	0.0787	0.5252	0.5746	0.2826
Environment*Breed	0.4494	0.8111	0.5466	0.8896	0.9509	0.5680
Sex*Environment	0.8868	0.9282	0.7767	0.4737	0.6782	0.4670
Sex*Breed	0.1213	0.7343	0.4422	0.5939	0.6646	0.3217
Sex*Environment* Breed	0.7252	0.6057	0.3469	0.6416	0.4929	0.8592

[1] LRLP=Light Restriction, Low Protein; CLHP=Constant Light, High Protein.

[2] Calculated as cumulative energy (ME) intake- carcass energy.

[3] Least square means for main effects of environment, breed, and sex is 36 reps per treatment.

TABLE 23. Cumulative carbon consumption by treatment, g per bird

	Age (d)					
	0-7	0-13	0-20	0-27	0-34	0-41
Environment[1]						
LRLP	50	142	374	755	1,254	1,813
CLHP	59	176	435	784	1,250	1,768
Breed						
Cobb	53	154	394	748	1,224	1,790
Ross	56	164	415	791	1,280	1,792
Sex						
Female	53	154	388	737	1,204	1,670
Male	56	163	421	802	1,300	1,912
	Probabilities					
Environment	<.0001	<.0001	<.0001	0.0650	0.8973	0.5551
Breed	0.0780	0.0027	0.0064	0.0062	0.0532	0.9851
Sex	0.0294	0.0033	<.0001	<.0001	0.0012	0.0047
Environment*Breed	0.1221	0.2639	0.2752	0.8369	0.9872	0.8248
Sex*Environment	0.9417	0.5690	0.6364	0.6818	0.9677	0.8080
Sex*Breed	0.2721	0.7063	0.4452	0.5115	0.6046	0.8113
Sex*Environment* Breed	0.8507	0.5935	0.5299	0.7174	0.4375	0.7196

[1] LRLP=Light Restriction, Low Protein; CLHP=Constant Light, High Protein.

[2] Least square means for main effects of environment, breed, and sex is 36 reps per treatment.

TABLE 24. Carbon rentention[2] by treatment, g per bird

	Age (d)					
	7	13	20	27	34	41
Environment[1]						
LRLP	22	49	123	257	432	587
CLHP	25	60	149	275	436	584
Breed						
Cobb	23	53	133	262	423	589
Ross	24	57	138	271	436	582
Sex						
Female	23	53	128	248	401	526
Male	24	57	143	284	467	644
	Probabilities					
Environment	<.0001	<.0001	<.0001	0.0056	0.7608	0.8902
Breed	0.0093	0.0015	0.1031	0.1490	0.7482	0.7343
Sex	0.0101	0.0007	<.0001	<.0001	<.0001	<.0001
Environment*Breed	0.0532	0.1200	0.3085	0.8930	0.9345	0.0918
Sex*Environment	0.8669	0.3266	0.6555	0.8991	0.7653	0.8642
Sex*Breed	0.5976	0.3028	0.7428	0.6776	0.6701	0.2360
Sex*Environment* Breed	0.4964	0.7488	0.9569	0.9745	0.5437	0.2286

[1] LRLP=Light Restriction Low Protein, CLHP=Constant Light, High Protein.

[2] Carbon retention=(carcass protein x 0.5296) + (carcass fat x 0.72).

[3] Least square means for main effects of environment, breed, and sex is 36 reps per treatment.

TABLE 25. Gaseous carbon[2] by treatment, g per bird

	Age (d)					
	7	13	20	27	34	41
Environment[1]						
LRLP	14	55	139	266	461	705
CLHP	16	63	159	275	450	668
Breed						
Cobb	15	57	144	259	436	684
Ross	15	63	153	282	474	689
Sex						
Female	14	57	145	267	559	669
Male	15	60	152	273	452	704
Probabilities						
Environment	0.0063	<.0001	<.0001	0.2901	0.3542	0.2523
Breed	0.6848	0.0739	0.0188	0.0109	0.0022	0.8936
Sex	0.1795	0.1276	0.0787	0.5252	0.5746	0.2826
Environment*Breed	0.4494	0.8111	0.5466	0.8896	0.9509	0.5680
Sex*Environment	0.8868	0.9282	0.7767	0.4737	0.6782	0.4670
Sex*Breed	0.1213	0.7343	0.4422	0.5939	0.6646	0.3217
Sex*Environment*Breed	0.7252	0.6057	0.3469	0.6416	0.4929	0.8592

[1] LRLP=Light Restriction, Low Protein; CLHP=Constant Light, High Protein.

[2] Gaseous carbon=((heat production x 4.184 J) /21.53)/22.4 L /mole x 44 g/mole x 0.2727 g C/g Co^2.

[3] Least square means for main effects of environment, breed, and sex is 36 reps per treatment.

TABLE 26. Carbon excreta[2] by treatment, g per bird

	Age (d)					
	7	13	20	27	34	41
Environment[1]						
LRLP	14	38	113	232	361	517
CLHP	19	53	128	234	365	513
Breed						
Cobb	17	44	117	227	356	515
Ross	17	47	123	239	369	515
Sex						
Female	16	44	115	221	344	474
Male	17	47	126	245	381	556
Probabilities						
Environment	<.0001	<.0001	<.0001	0.6545	0.6223	0.8507
Breed	0.0388	0.0014	0.0113	0.0115	0.1484	0.9893
Sex	0.0232	0.0015	<.0001	<.0001	<.0001	0.0017
Environment*Breed	0.0817	0.1427	0.2761	0.8039	0.9770	0.6534
Sex*Environment	0.8163	0.3703	0.6727	0.8469	0.9569	0.9443
Sex*Breed	0.3569	0.5414	0.5052	0.5213	0.6179	0.9996
Sex*Environment* Breed	0.7992	0.6076	0.6628	0.7692	0.4588	0.6158

[1] LRLP=Light Restriction, Low Protein; CLHP=Constant Light, High Protein.

[2] Calculated =Cumulative carbon intake-gaseous carbon-carcass carbon.

[3] Least square means for main effects of environment, breed, and sex is 36 reps per treatment.

TABLE 27. Percent carbon in gas produced[2], %

	Age (d)					
	7	13	20	27	34	41
Environment[1]						
LRLP	28	38	37	35	37	39
CLHP	26	36	36	35	36	37
Breed						
Cobb	27	37	36	35	36	38
Ross	27	37	37	36	37	39
Sex						
Female	27	37	37	36	38	40
Male	27	37	36	34	34	36
Probabilities						
Environment	0.0166	<.0001	0.3192	0.8649	0.2012	0.2153
Breed	0.3037	0.6571	0.3723	0.1575	0.0155	0.6812
Sex	0.8334	0.3205	0.0555	0.0034	<.0001	0.0029
Environment*Breed	0.9001	0.4952	0.6900	0.9318	0.9126	0.2302
Sex*Environment	0.9768	0.4653	0.9238	0.3934	0.4104	0.4438
Sex*Breed	0.0728	0.2930	0.6765	0.6863	0.7751	0.1612
Sex*Environment* Breed	0.3676	0.6547	0.4512	0.6865	0.9328	0.3987

[1] LRLP=Light Restriction, Low Protein; CLHP=Constant Light, High Protein.

[2] Calculated as gaseous carbon/cumulative carbon consumption.

[3] Least square means for main effects of environment, breed, and sex is 36 reps per treatment.

TABLE 28. Percent carbon in feces[2] by treatment, %

	Age (d)					
	7	13	20	27	34	41
Environment[1]						
LRLP	28	27	30	31	29	28
CLHP	32	30	29	30	29	29
Breed						
Cobb	30	28	30	30	29	29
Ross	30	28	30	30	29	29
Sex						
Female	30	28	29	30	29	28
Male	30	28	29	31	29	29
Probabilities						
Environment	<.0001	<.0001	<.0001	<.0001	0.0013	0.0236
Breed	0.2783	0.5739	0.4517	0.2075	0.0257	0.7034
Sex	0.8772	0.2653	0.0334	0.0014	<.0001	0.0016
Environment*Breed	0.8681	0.4683	0.6572	0.9453	0.9132	0.2226
Sex*Environment	0.9709	0.4518	0.9549	0.4101	0.4276	0.4572
Sex*Breed	0.0734	0.2833	0.7024	0.7154	0.7503	0.1756
Sex*Environment*Breed	0.3593	0.6695	0.4689	0.7006	0.8869	0.3802

[1] LRLP=Light Restriction, Low Protein; CLHP=Constant Light, High Protein.

[2] Calculated as carbon excreted/cumulative carbon consumption.

[3] Least square means for main effects of environment, breed, and sex is 36 reps per treatment.

TABLE 29. Percent carbon retention[2] by treatment, %

	Age (d)					
	7	13	20	27	34	41
Environment[1]						
LRLP	44	35	33	34	34	32
CLHP	42	34	34	35	35	33
Breed						
Cobb	43	35	34	35	35	33
Ross	43	35	33	34	34	33
Sex						
Female	43	34	33	34	33	32
Male	43	35	34	35	36	34
Probabilities						
Environment	0.0004	0.1804	0.0077	0.0919	0.4537	0.3502
Breed	0.3092	0.6757	0.3555	0.1473	0.0136	0.6757
Sex	0.8244	0.3334	0.0622	0.0042	<.0001	0.0034
Environment*Breed	0.9067	0.5012	0.6977	0.9286	0.9125	0.2330
Sex*Environment	0.9780	0.4683	0.9167	0.3897	0.4067	0.4410
Sex*Breed	0.0727	0.2951	0.6707	0.6796	0.7818	0.1582
Sex*Environment* Breed	0.3694	0.6516	0.4474	0.6833	0.9448	0.4046

[1] LRLP=Light Restriction, Low Protein; CLHP=Constant Light, High Protein.

[2] Carbon retention=Carbon retention / Cumulative carbon consumption x 100.

[3] Least square means for main effects of environment, breed, and sex is 36 reps per treatment.

CHAPTER IV

CONCLUSIONS

It is clear that the data shows little to no differences on day 41 between environment and breed. However, there are numerical differences that in the end can help mitigate greenhouse gas emissions. The constant light, higher protein environment (CLHP) had less heat production (kcals/g), less carbon excreted (g), and less gaseous carbon (g), but, the low protein, light restriction environment had higher carbon retention (g). Since lighting must be calculated in the greenhouse gas emissions, the data proves that even though constant lighting had less heat production, and less carbon excreted, a light restriction program gives the same results, making for a lower carbon footprint and ultimately lowering greenhouse gas emissions. Furthermore, the lower protein diet is cheaper to formulate and produces the same results as the higher protein diet. According to Cobb Vantress, feed is 60% of the cost of producing a broiler (2013). Feed cost for lower protein diet is $0.83 per bird, while a high protein diet is $0.84, suggesting a lower protein diet can lower the production cost without decreasing efficiency (Cobb Vantress, 2013).

Breed differences suggested that Cobb birds produced less ($P>0.10$) heat (kcals/g), less ($P>0.10$) gaseous carbon (g), and more ($P>0.10$) carbon retention. Male birds also had more ($P<0.05$) carbon retention. Ultimately suggesting that growing Cobb male birds under light restriction and a lower protein diet would not only produce a viable product in an efficient time it would decrease the greenhouse gas emissions.

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APPENDICES

Appendix Table 1

As Hatch Performance Objectives, Ross-308

Day	Body weight (g)	Cumulative Intake (g)	FCR
0	42	0	0
7	185	166	0.893
13	422	469	1.110
20	844	1,072	1.270
27	1,393	1,970	1.414
34	2,020	3,144	1.556
41	2,675	4,543	1.698

Appendix Table 2

As Hatch Performance Objectives, Cobb-500

Day	Body weight (g)	Cumulative Intake (g)	FCR
0	42	0	0
7	177	150	0.847
13	410	405	0.988
20	821	951	1.158
27	1,353	1,812	1.339
34	1,973	3,016	1.529
41	2,637	4,449	1.687

Appendix Table 3

As Hatch Carcass Yield, Ross-308

Weight (g)	%Breast (protein)	Protein (g)
1600	20.15	322.4
1800	20.49	368.8
2000	20.80	416.0
2200	21.10	464.2
2400	21.37	512.9
2600	21.62	562.12
2800	21.85	611.8

Appendix Table 4

As Hatch Carcass Cobb-500

Weight (g)	%Breast (protein)	Protein (g)
1600	20.70	331.2
1800	21.25	382.5
2000	22.12	442.4
2200	22.74	500.3
2400	23.31	559.4
2600	23.83	619.6
2800	24.26	679.3

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