2020

Incorporation of Hempseed in the Broiler Chicken Diet

Mallorie Alexzandra Snider

INCORPORATION OF HEMPSEED IN THE BROILER CHICKEN DIET

A Thesis
Presented to
the Faculty of the Department School of Agriculture
Murray State University
Murray, Kentucky

In Partial Fulfillment
of the Requirements for the Degree
of Master of Science

by Mallorie Snider
May 2020

INCORPORATION OF HEMPSEED IN THE BROILER CHICKEN DIET

DATE APPROVED: ____________________________

____

Thesis Advisor

____

Member, Thesis Committee

____

Member, Thesis Committee

____

Member, Thesis Committee

____

Member, Thesis Committee

Collegiate/School Graduate Coordinator

____

Dean of the College/School

____

University Graduate Coordinator

____

Provost

Acknowledgements

First, I would like to thank everyone who has contributed to my success during this time in my life. Without all of you, I would not feel as successful and thankful to have had this opportunity. To be able to conduct a research study this significant is beyond what I had expected when returning to acquire my master's degree.

My mom has always been my biggest fan and I would not have thought about coming back for my masters without her advice! I know she doesn't exactly know everything I do, but I know she is always in my corner. Without her support and push, I would not have excelled in this program. She has always been there to support my decisions and I am proud to say she is ALWAYS right. I would also like to thank my stepdad, Chris, for supporting me and offering to travel to help with my project this summer. I know he is always there to cheer for me. I love you both!

Dad, you have provided me with a life full of animals and I love you for that! My passion has turned into a career, all because of your help. Although my life has revolved around horses, I found a new calling beyond my expectations. I know you are extremely proud of me and I hope I keep making you proud!

One of the main contributors to my success is Dr. Brian Parr. Dr. Parr, you've had faith in me since day one. When I came to your office to ask if I could switch to the thesis route, you never hesitated. When I asked if there were any research projects I could help with, you commented, "Yeah, but it is a little odd. It involves chickens and hemp." When the words left your mouth, I already was thinking, "Yes, please!" Thank you for this amazing opportunity and for always believing in me. I never thought coming into this program, I would become a poultry and hemp researcher. I also never thought I would be afforded so many opportunities. Now, I don’t see how my life would be without it!

Of course, I could not have done this project without Dr. Tony Brannon. Dr. Brannon has been given the name, Dean of Hemp. They are not wrong by naming him this because he definitely knows his facts! I learned more about hemp and have been given the opportunity to go to a conference in Louisville because of him. I also was granted a position for the newly established Center for Agricultural Hemp as the research coordinator. Dr. Brannon, thank you for pushing me out of my comfort zone and believing in me! You and Dr. Parr have provided me with so many opportunities!

Dr. Guffey, I don’t know where to start. I have learned so much from you during my first semester in this program. I have become exceptionally confident while interacting with other professionals and presenting. I also know if I had anything to talk about, I could count on you! Thank you for providing your feedback and keeping it real for me.

Dr. Shultz, you are a ray of sunshine and I love talking to you! You are always so positive and appreciative of everything and I adore that. Thank you for helping me with my statistics and for being up for random discussions. I know there is still much to learn!

HuiChang, we went through a lot during the summer of 2019. It was hot, humid and most days, we weren’t sure how we would get the work done. We made it! Working with you was great and I learned a lot from you. Thank you for always having a positive attitude and providing so many laughs. I think we will both remember the summer of 2019, where we had to deal with those hemp-fed chickens.

Abstract

Hempseed has become a popular supplement alternative due to the confounding nutritional benefits it possesses; however, the legality of hempseed, and other hemp products, prevents the use in animal feeds. Particularly, broiler chickens that grow fairly quickly in a short amount of time. Evaluation of hempseed in the broiler chicken diet is needed to conclude if it is a possible replacement for other broiler nutrient sources, such as soybean meal (SBM). Thus, the objective of this study was to evaluate effects of hempseed (HS) on the growth, feed conversion and carcass yield of broilers. This study consisted of 48 Ross 708 broilers housed in individual cages. The broiler diets consisted of a grower concentrate with: Control (0% HS, 15% SBM), 10% HS (5% SBM) and 15% HS (0% SBM). Body weights, feed conversion ratios and carcass yields were measured. Net weight gain was observed, $F(2, 45) = 1.45$, $p = 0.25$, where no diet group was significant. Average daily weight gain was similar $F(2, 45) = 1.18$, $p = 0.32$. However, the feed conversion ratio (FCR) was statistically significant $F(2, 45) = 4.39$, $p = 0.02$, resulting in the Control diet to have the best FCR and the 15% HS diet with the worse FCR. Carcass yield was not significant $F(2, 45) = 2.93$, $p = 0.06$. Data indicates the hempseed diets did not benefit the broilers' performance, however, the feed analysis determined the hempseed fiber content was higher than recommended for broiler nutrition. Adjustments to the diet should be made to determine the correct amounts of protein and fiber.

Table of Contents

List of Tables

List of Figures

Chapter I

Incorporation of Hempseed in the Broiler Chicken Diet

Broiler chickens are a prevalent aspect of agriculture, immensely bred, raised and processed for meat production and consumption. In the United States, the market for broiler chickens are high. "The broiler industry is the most advanced system of animal food production and the United States has the world's largest broiler industry" (USDA, 2013, Scope of the Broiler Industry section, para. 1). Throughout the United States, broiler chickens provide economic growth with millions of jobs and revenue within the industry. In 2018, data released by the U.S Poultry & Egg Association stated the poultry industry provides 1,393,739 jobs, $76.5 billion in wages, $347.1 billion in economic activity and $27.0 billion in government revenue (U.S. Poultry & Egg Association, 2018). Accordingly, 40 companies have contracts with farmers across the United States, with the top two companies being Tyson Foods, Inc. and Pilgrim's Pride (USDA, 2013, Scope of the Broiler Industry section, para. 1).

As an excellent source of protein, chicken meat is also low in fat (Erdis, Henmat, Shaltout, Elshater & Eman, 2012). Due to the low-fat content, chicken meat is identified as a lean protein and is desired for different cooking methods. In turn, the broiler industry has expanded due to the increase in poultry meat consumption. This has raised concerns for broiler growth and yields. "It is well known that this huge demand for poultry meat has put pressure on breeders, nutritionists and farmers to improve the growth rate of birds, feed efficiency and breast-meat yield" (Petracci, Mazzoni, Meluzzi & Sirri, 2013, p. 2438). Broiler chickens have an average growth cycle of six weeks, with an average ending weight of 2.5 kg or 5.5 lbs. This is possible through feed conversion ratios (FDR) per pound of body weight (Punda & Prikhodko, 2010).

Soybean meal (SBM) is a prominent protein source for broiler chickens. SBM is utilized in non-ruminant animal nutrition, but it varies in quality and expense, which could be unavailable to developing countries (Erdaw, Perez-Maldonado, & Iji 2017). Discovering alternative protein supplements may change broilers' growth rate and carcass weight. To achieve enviable results, mixing various nutritional additives to broiler feed will boost net return and decrease feed cost (Khan, Durrani, Chand, Anwar, 2010).

Cannabis sativa L, or hemp, is a potential alternative to soybean meal supplementation for meat poultry. Hemp possesses characteristics which may be beneficial to the broiler chicken diet, however there are a few concerns. Hemp contains a metabolite called cannabidiol (CBD), the non-psychotic cannabinoid derived from tetrahydrocannabinol (THC) (Šťastník, et al., 2019, p. 121). Hempseed fed to poultry may contain THC; potentially a source of concern for the consumer. "Tetrahydrocannabinol is a potent lipophilic antioxidant with appetite-stimulating properties" (Šťastník, et al., 2019, p. 121). However, per USDA regulations, hemp is only allocated 0.3% or lower of THC.

Statement of the Problem

Hempseeds have high levels of protein, which may potentially replace soybean meal as a protein supplement for broilers' diets. Furthermore, feeding hempseed to broilers may provide a faster growth rate and overall weight gain. There are few studies shown on the supplementation of hemp to broiler chickens. This is due to the illegitimacy of feeding hemp to animals for human consumption. The Federal Food and Drug Administration (FDA) has not approved industrial hemp for use in animal feeds (AAFCO, 2019).

Purpose of the Study

The purpose of this study was to determine the effects crushed, whole hempseed has on the growth, livability, palatability and production on Ross 708 broiler chickens. The growth rate in broiler chickens are vital for farmers to provide multiple broiler flocks within a year. Examining these characteristics while feeding hemp to broilers will provide more scientific information. Analytics of the feed given to the broilers will also provide insight.

Research Questions/Hypotheses

The following research questions are disclosed:

1. Could hempseed replace soybean meal as a protein supplement for meat poultry?
2. Do broilers have a higher feed conversion ratio when fed hempseed?
3. Will feeding hempseed allow broiler chickens to grow at the same rate as soybean meal-fed broilers?
4. Does hempseed affect carcass yield?
5. Will the feed analysis provide adequate information over nutrient content?

Definition of Terms

ADWG – Average Daily Weight Gain

Broilers – Meat chickens

Cannabis sativa L – Hemp

CBD - Cannabidiol

Cockerel – Young rooster (male)

EFA – Essential fatty acids

FCE- Feed Conversion Efficiency

FCR – Feed Conversion Ratio

g – gram

HS - Hempseed

kg – kilogram

lbs – pounds

Omega-3 – alpha-linolenic acid

Omega-6 – linoleic acid

Poultry – Chickens

PUFAs – Polyunsaturated fatty acids

Pullet – Young hen (female)

SBM – Soybean Meal

TDN- Total Digestible Nutrients

THC – delta-(9)-tetrahydrocannabinol is one of the psychoactive ingredients in the cannabis plant

Limitations

The following are limitations of this study:

1. Only 48 broiler chickens were used in this study.
2. Crushed, whole hempseed was used rather than hemp byproducts or hemp hearts.
3. Facility utilized was not weather-controlled.
4. Broilers were a mixed gender.
5. Broilers were only one breed.

Assumptions

The following are assumptions of this study:

1. All broiler chickens are the same age.
2. Each broiler was fed the same amount of feed each day.
3. The three groups are fed the same feed conversion ratio (FCR) according to the group.
4. Broilers stay hydrated and as comfortable as possible in all weather conditions from May to July.
5. Feeding hempseed to broilers provides enough protein supplementation for full growth. Broilers grow close to the same rate as those fed soybean meal.

Significance of the Study

Replacing soybean meal with hempseed may benefit the poultry industry by providing another protein supplement. "The relative high crude protein of the hemp seed cake indicates that it may be used most efficiently as a protein supplement in animal feeds" (Febles, CRD NC State Extenstion, & Edmisten, 2018). Utilizing the seeds of hemp will provide a new agricultural market and reduce waste of hemp. The cost effectiveness for using hempseed as a protein source may lower costs for poultry farmers. Data from this study will allow researchers and poultry farmers information regarding protein supplementation utilizing hemp. The growth rate, livability and palatability of hemp-fed broiler chickens are included in this study. The nutritional value of the broiler feed and additives utilized are also included.

Chapter 2

Literature Review

This chapter reviews related literature for this research study. This review will highlight the broiler chicken industry, nutrition practices, and hemp as a nutrient. The following sections are in this review: Introduction, Broiler Chicken Nutrition Requirements, Analysis of Meat Deposits and Quality, Related Feed Practices, Hemp Nutritional Content, Hemp Trials for Use in Poultry Nutrition and Hemp Regulation for Animal Use.

Broiler Chicken Nutrient Requirements

With the increasing demand for protein in the form of chicken meat, nutritional requirements for broiler chickens has changed over the years. "In the last 50 years, consumption of poultry meat has increased rapidly, and it is supposed that it will continue to grow in the future, particularly in the developing countries" (Petracci, Mazzoni, Meluzzi, & Sirri, 2013, p. 2438). In turn, leading the broiler industry to increase productivity with quick flock turnover rates. Advancement in broiler nutrition will achieve the demand of rapid growth and sustainability for broiler production (Beski, Swick, Iji, 2015).

The nutritional requirements for broilers is similar to other meat animals, but unique due to their fast-growing rate. "When formulating broiler diets, the main emphasis is placed on the crude protein (CP), because protein is the critical constituent of poultry diets, and together with the other main nutrients such as carbohydrates, fat, water, vitamins, and minerals, is essential for life" (Beski, Swick, Iji, 2015, p. 47). Protein is essential for the broiler chicken diet; however, it can also be expensive. One of the common proteins used in the broiler diet is plant-based, soybean meal (SBM). The crude protein of SBM is between 40% and 48%, dependent on the quality (Beski, Swick, Iji, 2015, p. 48). However, SBM does contain anti-nutritional factors (ANFs), which have trypsin inhibitors, lectin and phytic acid (Erdaw, Perez-Maldonado, & Iji, 2017, p. 533). This could lead to a potential lower nutritional value.

There are other important components to a broiler chicken's diet that contribute to faster growth and meat quality. Different fat grades are used in broiler feed to provide energy. When fat is added to the diet for energy requirements, there is usually an excess of linoleic acid based on corn and SBM diets (Pesti, Bakalli, Qiao & Sterling, 2002). Linoleic acid, found in fat, is an essential nutrient in the broiler chicken diet. Another essential for the meat chicken diet is, sodium chloride for metabolite balance.

> However, because of their important metabolic effects on nerve cells, acid-base balance, osmotic pressure regulation, and monosaccharide and amino acid absorption, it is necessary to supply them in precise levels and adequate balance for optimum growth, bone development, and good litter quality (Murakami, Oviedo-Rondon, Martins, Pereira, & Scapinello, 2001, p. 289).

Additionally, fiber content in the broiler diet is essential for healthy gut flora and growth. However, when there is not a minimal amount of fiber, birds have the potential to show abnormal behaviors such as feather peaking and litter consumption (Mateos, Jiménez-Moreno, Serrano, & Lázaro, 2012). Reaching the minimal amount of this nutrient can positively affect gut flora, digestive health and broiler performance. On the contrary, too much fiber may have negative effects, reducing performance and gut health. The source of fiber, age and breed of the broiler will determine the formulation for minimum and maximum amount of fiber needed in the broiler diet (Mateos, et al., 2012).

Moreover, there are many more components to the broiler diet that are essential for growth performance. Nutritionists and poultry farmers are seeking ways to substitute or transition diets to incorporate higher nutritional values. In turn, leading to higher profitability and broiler performance efficiency.

Analysis and Quality of Poultry Meat

Broiler chicken meat is analyzed for fat deposits and quality. With higher demand for lean protein, there is also a demand for less fat in chicken meat. “The success of the poultry industry depends on enhancing growth performance and carcass characteristics, reducing fat deposition of growing broiler chickens and improving the products offered to consumers” (Milanković, et al., 2019, p. 508).

Lesson and Zubair conducted a study to determine if restricting broilers’ diet during the early life will show leaner body composition and higher growth rate. The results showed a lack of significance in the three experiments. “In general, there does not seem to be any advantage to manipulating diet formulation during re-alimentation of birds previously nutrient-restricted” (Leeson and Zubair, 1997, p. 992).

Milanković, et al. researched feeding broilers linseed and/or lard and analyzing fatty acids in meat and weight of different cuts of meat. The broilers fed the linseed had a higher weight in carcass cuts, but was not significantly different. However, the broilers fed linseed oil showed more linoleic acid. "The dietary incorporation of linseed oil and pig lard during starter, grower and finisher phases can enrich broiler chickens' meat with n-3 PUFA. This study has clearly shown that linseed oil in broiler nutrition provided the best n-6/n-3 ratio" (Milanković, et al., 2019, p. 507).

Furthermore, managing nutrition to regulate body fat deposition for leaner meat is essential for higher carcass yield. Formulating a diet for a specific strain of broiler will reduce issues of excess abdominal body fat. This may be done by replacing saturated fatty acids with polyunsaturated fatty acids and/or supplements (Fouad & Senousey, 2014).

Related Feed Practices

To better understand the components of hemp as a feed additive, the analysis of varying nutritional trials for broiler chickens will provide more information. The University of Illinois conducted a study of the nutritional value of soybean meal varieties on broiler chickens (Baker, Utterback, Parsons & Stein, 2011). In their study, they had three experiments – high protein (SBM-HP), low-oligosaccharide (SBM-LO), and conventional (SBM-CV). They determined amino acid digestibility and growth performance. Baker et al., found no differences between the groups in growth performance and feed intake. "SBM-HP and SBM-LO have a greater nutritional value in diets for broiler chicks because of the increased concentration of digestible AA, which reduces the quantity of SBM that is needed in the diet" (Baker, Utterback, Parsons & Stein, 201, p. 395).

According to Khoddami, Chrystal, Selle and Liu, the starch to lipid ratios in a broiler chicken's diet is important. There are not many resources depicting the correlation for these energy sources in the modern broiler's diet. Khoddami et al., used oats, maize, soybean meal and other resources to utilize different starch and lipid ratios. In this study, they found, "increasing nutrient density, increased weight gain, decreased feed intake and improved feed conversion efficiency in broiler chickens from 7 to 27 days post-hatch" (Khoddami, Chrystal, Selle, & Liu, 2018, p. 15). In their findings, lipids had more of an impact in feed intake, but starch allowed more energy to produce higher lipid concentrations in broiler carcass'.

Additionally, a study utilizing flaxseed, broken rice and distillers dried grains with solubles (DDGS) determined an alteration of fatty acids and oxidative stability in poultry meat. (Mir, et al., 2018). This included six different diets with a control and five different percentages of the added grains. Their findings suggested flaxseed increased the feed intake, reduced FCR, increased omega-3/6 and reduced fat and cholesterol, which may reduce risk of cardiovascular diseases. (Mir, et al., 2018). However, when flaxseed and DDGS are included in the diet, the FCR and oxidative stability of the meat reduces shelf life and profitability. In conclusion, the study suggests added another antioxidant suitable for the broiler diet (Mir, et al., 2018).

Hemp Nutritional Content

Hemp as a nutritional element to the poultry diet opens a new domain. To better understand hemp fed to poultry, considerations should be made about the nutritional content of hemp. Hempseed consists of 25% protein, 30% oil, fiber, vitamins and minerals (Calloway, 2014). Not only that, but hempseed oil has about 80% PUFAs and is rich in EFAs, omega-6 and omega-3. (Calloway, 2014). Provided this information, hempseed and hempseed oil are considered excellent for human health. Animals need fatty acids in their diet -- linoleic acid, arachidonic acid, alpha-linolenic acid (Crescente, et al., 2018).

The hempseed, as stated above, provides the needed nutrients for humans and animals. Hempseed protein (HSP) is highly digestible with amino acids compared to soy protein isolate (SPI) (Wang, Tang, Yang, & Gao, 2008). The fatty acid content of hempseed displays the main nutritional value, but there are a couple other nutrients that benefit as well. Hempseed oil's efficiency as a functional food is increased by the natural products B-sitosterol and methyl salicylatecomplement (Leizer, Ribnicky, Poulev, Dushenkov, & Raskin, 2000).

Hemp Trials for Use in Poultry Nutrition

Hemp is a potential energy protein for animal nutrition, including meat poultry. Although hempseed feeding trials are relatively recent, there are studies that suggest hemp as a protein source in poultry. The amounts of hempseed or hemp derivatives are also under question. "Data from feeding trials indicate that hempseed cake could be used up to 20% in laying hens' diets; it is concluded therefore that not more than 10% can be used in diets for chickens for fattening" (EFSA, 201l, Conclusions on the potential use of hemp products in animal nutrition, para. 2). The EFSA concluded three study trials feeding hemp to laying hens from 2005 to 2010. In EFSA's findings, hempseed meal (HSM) increased yolk color intensity, body weight, egg weight in two of the studies. In the 2005 study, there were no differences between HSM fed chickens and control. However, there were "lower concentrations of palmitic acid and higher concentrations of linoleic and α-linolenic acids" (Silversides & Lefrancois, 2005, p. 231).

Ondrej, et. al, produced a study involving the performance of broiler chickens fed hempseed cake. They had 75 Ross 308 cockerels split into three different nutritional groups; two experimental and one control. The control group did not contain hempseed cake, but the other two groups consisted of 5% and 15% hempseed cake. The 15% hempseed cake diet had a poor feed conversion ratio and live weight (Ondrej, et. al, 2015). In conclusion, they found the higher concentration of hempseed cake negatively affected the broiler chickens' overall body weight and there was a significant difference in body weight between the three groups.

Another study from Khan, Chand, & Anwar examined the growth, feed intake and FCR in four different groups of 160 commercial broilers; control, 5% hempseed, 10% hempseed and 20% hempseed. "The positive effect of broiler performance in this experiment indicates the nutritive effect of *Cannabis sativa* seed" (Khan, Durrani, Chand, & Anwar, 2010, p. 36). In the results of this study, there were significant differences between the four groups. Feed consumption being higher in the control group, but lower in weight and weight being highest in the 20% group with the lowest feed consumption.

In 2002, Silversides, et al., fed hempseed meal to laying hens at four different levels; 5%, 10%, 20% and control. The study found the HSM did not affect the feed consumption, efficiency, growth nor egg production (Silversides, Budgell & Lefrancois, 2002). Additionally, the study found there was an increase in linoleic and alpha-linolenic acids in the yolk of the eggs. "Hempseed meal provided in the diets of laying hens may provide an alternate feed source rich in protein" (Silversides, Budgell, & Lefrancois, 2002, para. 3).

Additionally, a research study determined hempseed did not provide a noticeable change of weight gain, FCR, feed consumption nor carcass weight, but improved the gut flora in broilers (Vispute, et al., 2019). This study also concluded hempseed improved and altered the serum lipid profile of the broilers, decreasing cholesterol and increasing performance.

Moreover, previous research from Murray State University concluded broilers fed a hemp heart diet increased broiler performance. Compared to a SBM based diet, broilers fed a 20% hemp heart diet gained more weight and had a lower FCR (Hooks, Parr, Brannon, Chae & Snider, 2020). The results were statistically significant for the net weight gain and feed conversion, signifying the control and 20% hemp heart diets were different. (Hooks, et al., 2020).

Hemp Regulation for Animal Use

Although there have been research trials feeding hemp to poultry and other animals, it is not legal in the United States to feed hemp commercially. “The 2018 Farm Bill did not grant the right to use hemp and hemp products in food for humans or animals. The FDA has regulatory authority over food products” (AAFCO, 2019, p. 1).

Due to this, feeding hemp products to animals is allowable only in research trials that are approved according to the 2018 Farm Bill. This restriction is also due to the lack of research. “No data are available concerning the likely transfer of THC and its lipophilic metabolites to animal tissues and eggs following repeated administration” (EFSA, 2011, p. 2). There are regulations set that require hemp to have less than 0.3% THC. “Industrial hemp means the plants and plant parts of the genera *Cannabis*, the leaves and flowering heads of which do not contain more than 0.3% Δ-9 tetrahydrocannabinol" (Gakhar, Goldberg, Jing, Gibson, & House, 2012, p. 701).

Summary

In conclusion, the broiler chicken industry is changing due to consumer demand for leaner protein and poultry farmers' needing higher turnover. The broiler diet consists of high protein elements, but also many essential fatty and amino acids. The FCR is an important aspect to determine best feeding practices for less fat deposits and higher carcass weight. Utilizing hemp as a nutritional element may help with the protein requirements needed for broiler needs. However, more research trials need to be conducted to determine if hemp is a reliable protein and energy source for poultry nutrition. This will also rule out if the THC in hemp transfers to poultry products and the legalization of hemp in animal nutrition.

Chapter 3

Methodology

This chapter consists of material referring to the methodology used in this research study. The structure of the methodology will determine the relevance of diet, growth and carcass yield between a control group and two experimental groups. The following are sections in the methodology: Research design, subject selection, data collection procedures, data analysis procedures, budget and time schedule, references and appendices.

Research Design

Design

This study utilized a randomized experimental design. The broilers were randomly assigned to one of three groups: a control and two experimental groups.

Variables

The variables in this study were the broilers' diet and final growth weight. Each broiler chicken was randomly assigned to a diet of a control group or two different experimental groups. The independent variable consisted of three different diets chosen for the study. The dependent variable was how much weight each broiler chicken gained each week and at the end of the experiment. Confounding variables include consumption of feed and weather. During the hot days of the summer, feed consumption decreased.

Subject Selection

Population

Broiler chickens were donated for this research study from Pilgrim's Pride made possible by Jamie Guffey, executive director of the Kentucky Poultry Federation. 48, 1 day old broiler chicks were selected for this study. The breed of the broiler chickens was Ross 708. The population consisted of straight run, mixed genders of male and female. Animal care guidelines were conducted and approved under the Institutional Animal Care and Use Committee (IACUC).

Sampling Procedure

Forty-eight, one-day old broiler chicks were housed under a heat lamp in a large cage for two weeks and fed chick starter, in a shared feeder. After two weeks, the broiler chicks were separated into three different, randomly assigned groups of 16, for one week. At four weeks of age, each chick was assigned their own individual cages and remained in assigned cages throughout the study. Each cage was labeled as control, experiment one or experiment two.

Instrumentation

Development Procedures and/or Instrumentation

Feed conversion ratio or efficiency (FCR/FCE) was calculated by the beginning body weight, intake of feed and growth rate (Skinner-Noble & Teeter, 2003). The FCR was utilized for each individual broiler and overall growth from each group per week and final live weight.

Average Daily Gain (ADG) was calculated by subtracting the starting weight by the end live weight and dividing by the number of days in between. In this case, it would be 29 days.

Validity and Reliability of Instruments

Feed conversion ratio (FCR) is strongly considered a resourceful tool to determine total conversion of amount of feed into the total amount of weight gain (Willems, Miller & Wood, 2013). "Selection for FCR will improve efficiency of feed utilization" (Aggrey, Karnuah, Sebastian, & Anthony, 2010, para. 4). Therefore, FCR is needed to determine which feed products to provide for broiler nutrition. Average Daily Gain (ADG) is needed to calculate FCR, but also to determine overall weight gain of each group in the study.

Data Collection Procedures

At the age of four weeks old, 48 Ross 708 broiler chickens were divided into three different groups. The treatment diets consisted of three diets, a control and two experimental diets. The broilers were started on a grower concentrate feed along with added supplementation. The Control diet comprised of 15% soybean meal (n=16) and no hempseed was added, the first experimental diet comprised of 10% hempseed and 5% soybean meal (n=16) and the second experimental diet comprised of 15% hempseed (n=16). Before switching from starter feed to grower concentrate, each individual broiler was weighed to establish a starting weight. Each broiler's weight was measured at four, five, six, seven and eight weeks of age, using a heavy-duty digital scale. Carcass weight was also measured after processing. Every day, the feed intake of each broiler was weighed with a digital kitchen scale and recorded. Each broiler had individual feeders and drinkers, which were cleaned and replenished every day. Broilers had *ad libitum* access to water and feed. Each broiler was fed commercial grower concentrate with the control or experimental diets added. The control and experimental feeds were calculated upon broiler industry standards.

Data Analysis Procedures

ANOVA Single Factor was utilized to determine the effects of the hempseed diets which were evaluated for: net weight gain, feed conversion ratio, average daily gain and net carcass weight of each group of broilers. In addition, standard deviation provided a measure of variability for growth performance and feed intake. Moreover, the average growth and feed conversion ratios were observed for each group.

Budget and Time Schedules

Budget

Although the chickens and feed components were donated, an estimation of feed expense is in the table below. The facilities, cages, feeders, waterers and other supplies were already available. Three heavy duty fans were purchased to help circulate air and keep broilers cool during high temperatures. Small purchases were made on zip ties and a second kitchen scale. Two graduate students were paid during this study at $10.00 per hour, 20 hours per week.

Table 1

Budget for Inclusion of Hempseed in the Broiler Chicken Diet

Product Type	Cost ($)
Feed	5,000
Fans	200
Graduate Assistants	2,400
Miscellaneous	40
Total	7,640

Time Schedule

The broilers were brought to the Murray State University West Farm on June 3, 2019. Every day, twice a day, the chicks had their feed and water replenished. Trays under each cage held shavings to capture waste, which were changed once a week. Two times a day, two hours a day, each individual broiler was fed and watered, as well as, feed consumption measured. Once a week, the waste was disposed of and shavings replenished, which took about one hour. Once a week, weighing each individual broiler took around 30 minutes. The broilers were sent to the USDA-certified processing plant on August 1, a round trip of two hours and 40 minutes.

Chapter 4

Results

This chapter consists of the results from this research study. The results will examine the broiler net weight gain, feed conversion, average daily weight gain, net carcass weight and feed analysis. Additionally, the resulting findings are expressed in figures and tables.

Net Weight Gain

The live net weight gain of each individual broiler was obtained ($n=48$). The three groups, Control, experiment one (10% Hempseed) and experiment two (15% Hempseed) were compared to each other to determine the difference of weight gain between groups. The results of the ANOVA analysis were not statistically significant $F(2, 45) = 1.45$, $p = 0.25$. The ANOVA yielded a small effect size ($\eta 2 = 0.06$).

The effect of HS on the growth of the broiler diet groups are expressed in Figure 1. The Control diet contained 0% Hempseed and 15% SBM, which had the highest net weight gain of the three groups, the minimum weight being 4.56 lbs. and the maximum weight being 7.86 lbs. The 10% Hempseed diet contained also 5% SBM, but gained less than the Control with the minimum weight at 4.52 lbs. and the maximum weight at 7.45 lbs. The 15% Hempseed diet contained no SBM and had a minimum weight of 4.46 lbs. and a maximum weight of 7.35 lbs. The average net weight gain of each group was: Control 6.19 lbs. (SD = 0.97), 10% Hempseed 6.02 lbs. (SD = 0.94), 15% Hempseed 5.66 lbs. (SD = 0.72). The overall average net weight gain for all groups was 5.96 lbs.

The average ending live weight was: Control 7.09 lbs., 10% Hempseed 6.79 lbs., 15% Hempseed 6.57 lbs. The standard deviation error value is depicted in Figure 2. The Cohen's D effect sizes were as follows: Control and 10% Hempseed 0.18, 10% Hempseed and 15% Hempseed 0.42, Control and 15% Hempseed 5.43.

Figure 1

Broiler Net Weight Gain by Diet

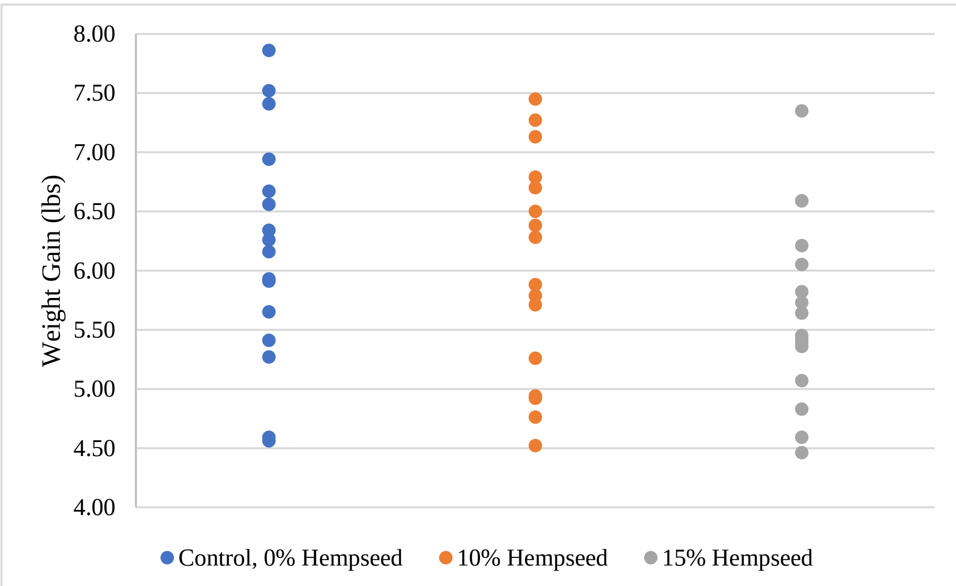
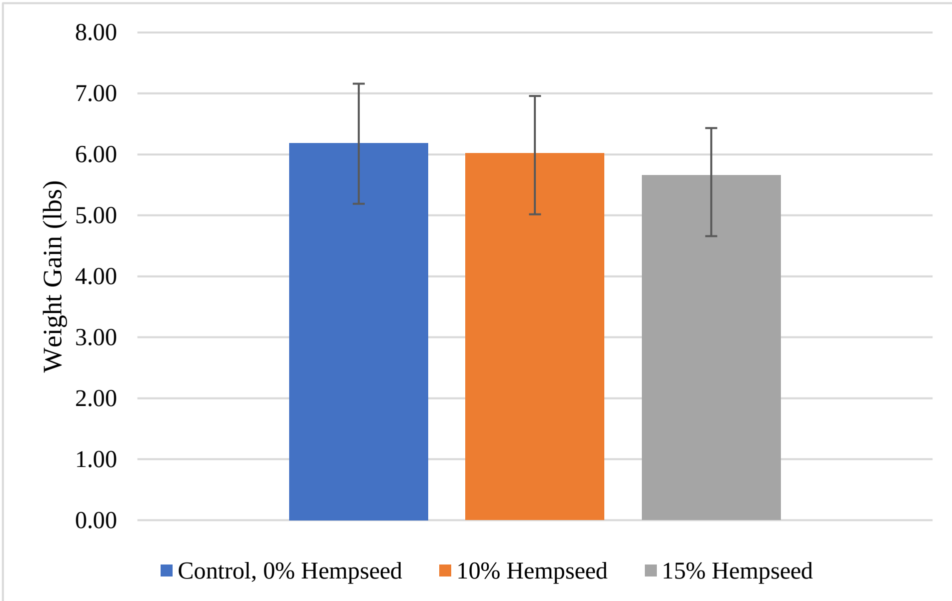


Figure 2

Standard Deviation Error Value of Net Weight Gain by Diet



All three of the two-sample post-hoc tests were not statistically significant, at an alpha level of 0.05. Control and 10% Hempseed $t(30) = 0.51$, $p > 0.05$; 10% Hempseed compared to 15% Hempseed $t(29) = 1.18$, $p > 0.05$; and Control compared to 15% Hempseed $t(29) = 1.71$, $p > 0.05$. The resulting Post-Hoc tests are shown in Tables 2, 3 and 4. The Cohen's D effect size of each diet group was large.

Table 2

Results of Post-Hoc Test on Net Weight Gain Between Control and 10% Hempseed (n=32)

	Mean	*df*	*p*	*t*
Control	6.19	30	0.61	0.51
10% Hempseed	6.02			

Table 3

Results of Post-Hoc Test on Net Weight Gain Between 10% Hempseed and 15% Hempseed (n=32)

	Mean	*df*	*p*	*t*
10% Hempseed	6.01	29	0.25	1.18
15% Hempseed	5.66			

Table 4

Results of Post-Hoc Test Net Weight Gain Between Control and 15% Hempseed (n=32)

	Mean	*df*	*p*	*t*
Control	6.19	29	0.10	1.71
15% Hempseed	5.66			

Feed Conversions

The consumption of each individual broiler (*n=48*) was measured every 24 hours. The FCR was calculated by dividing feed consumption by net weight gain in pounds. Additionally, the feed conversion ratios were compared between the three groups of broiler diets.

The average feed conversions were: Control 1.59 lbs. (SD = 0.12), 10% Hempseed 1.71 lbs. (SD = 2.4), 15% Hempseed 1.79 (SD = 0.19). The overall average FCR was 1.70 lbs. Figure 3 depicts the feed consumption per weight gain. The error value of standard deviation is indicated in Figure 4. The results of the ANOVA analysis were statistically significant $F(2, 45) = 4.39$, $p = 0.02$. The ANOVA yielded a large effect size ($\eta 2 = 0.16$).

Figure 3

Feed Conversion by Broiler Diet

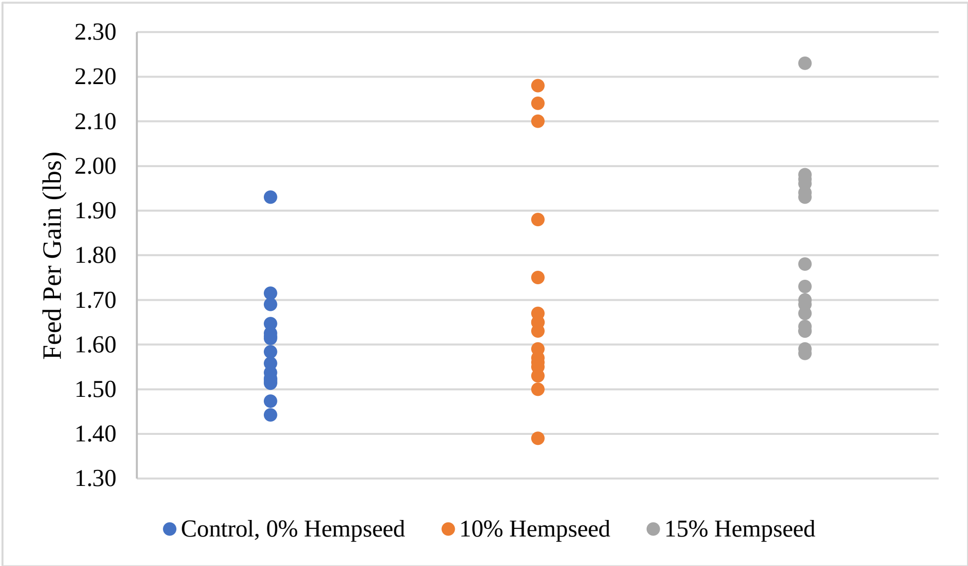
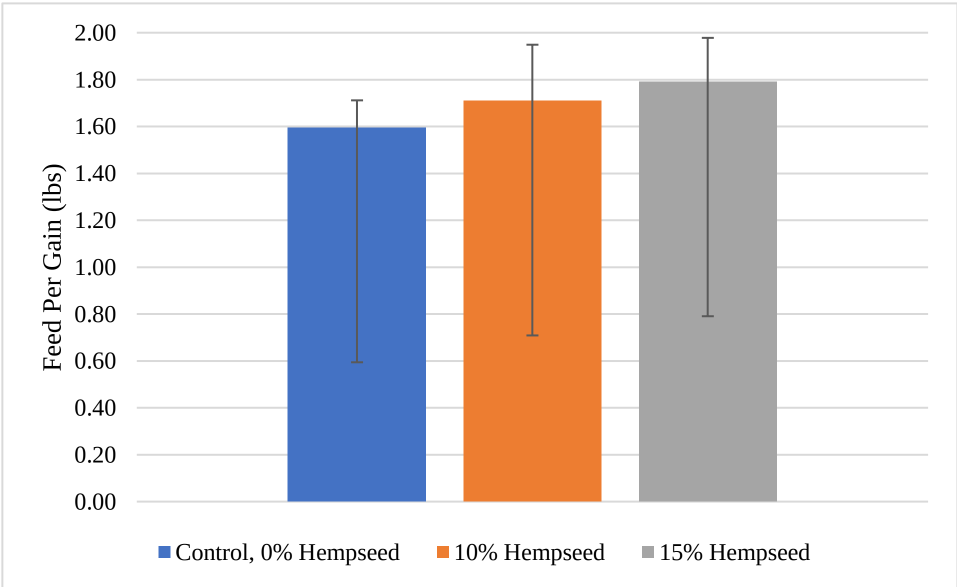


Figure 4

Feed Conversion Per Diet with Standard Deviation Error Value



Three independent t-tests were conducted between the three diet groups at an alpha level of 0.05. The following group yielded a statistically significant feed conversion: Control compared to 15% Hempseed $t(25) = -3.6$, $p < 0.05$. 10% Hempseed compared to 15% Hempseed was not statistically significant: $t(28) = -1.08$, $p > 0.05$. The Control compared to 10% Hempseed was not statistically significant: $t(22) = -1.71$, $p \geq 0.05$. The Cohen's D effect size of each diet group was large, except between the 10% and 15% HS diet groups which was medium. Tables 5, 6 and 7 express the post-hoc analysis.

Table 5

Results of Post-Hoc Test on Feed Conversion of Control and 10% Hempseed (n=32)

	Mean	*df*	*p*	*t*
Control	1.59	22	0.1	-1.71
10% Hempseed	1.71			

Table 6

Results of Post-Hoc Test on Feed Conversion of 10% Hempseed and 15% Hempseed (n=32)

	Mean	*df*	*p*	*t*
10% Hempseed	1.71	28	0.29	-1.08
15% Hempseed	1.79			

Table 7

Results of Post-Hoc Test on Feed Conversion of Control and 15% Hempseed (n=32)

	Mean	*df*	*p*	*t*
Control	1.59	25	0.002	-3.55
15% Hempseed	1.79			

Average Daily Weight Gain

The weight of each broiler was measured once a week utilizing a calibrated scale. ADWG was calculated by subtracting the initial broiler weight by the final broiler weight and dividing by 29 days, which was the length of this research study. Note the initial weight was taken when the hempseed was added to the diets. Additionally, ADWG was compared between all three diet groups (*n*=48).

The ADWG per diet group was: Control 0.47 lbs. (SD = 0.07), 10% Hempseed 0.46 lbs. (SD = 0.07), 15% Hempseed 0.43 lbs. (SD = 0.06). The overall ADWG for all broilers was 0.45 lbs. Figure 5 expresses the effect of HS on the ADWG per diet. Standard Deviation was used to demonstrate the error value of ADWG per diet, depicted in Figure 6. ANOVA analysis deemed ADWG not statistically significant $F(2, 45) = 1.45$, $p = 0.25$. The ANOVA yielded a small effect size ($\eta 2 = 0.06$).

Figure 5

Average Daily Weight Gain by Diet

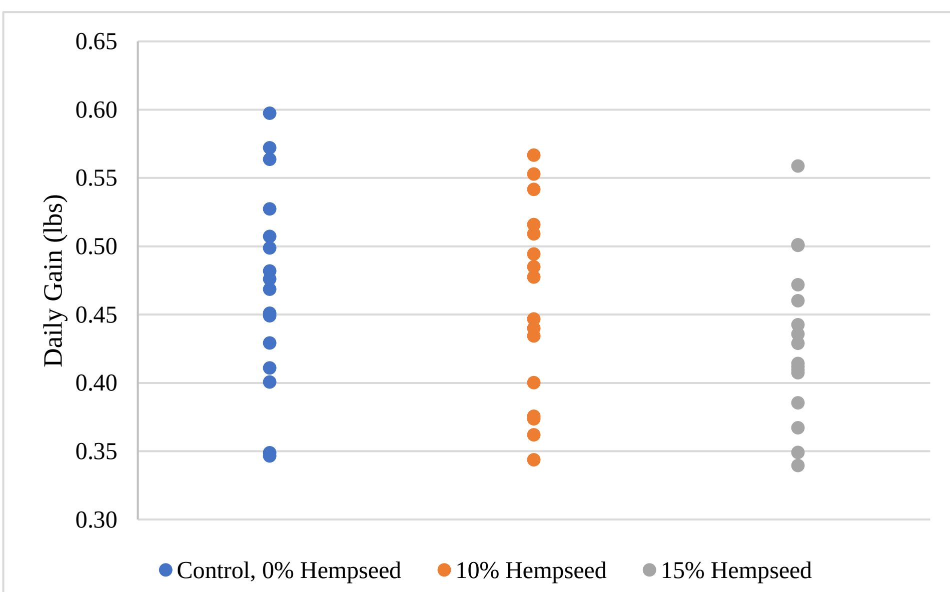
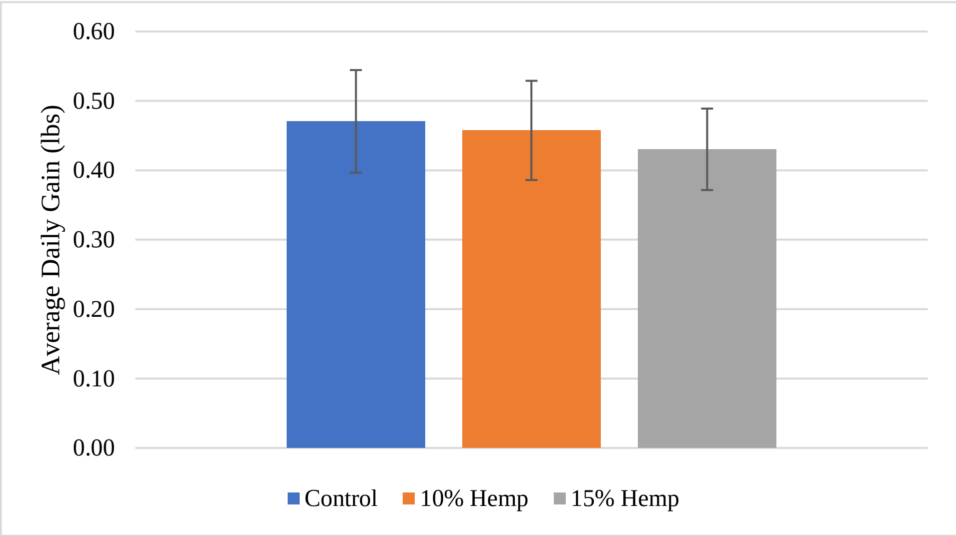


Figure 6

Standard Deviation Error Value of Average Daily Weight Gain by Diet



Post-hoc analysis was done with three independent *t*-tests, identified in Tables 8, 9 and 10. All groups were not statistically significant: Control compared to 10% Hempseed $t(30) = 0.51$, $p > 0.05$; 10% Hempseed compared to 15% Hempseed $t(29) = 1.18$, $p > 0.05$; Control compared to 15% Hempseed $t(29) = 1.71$, $p > 0.05$. The Cohen's D measure of effect size was medium for the 10% and 15% HS diets, but large for the control and 10% HS diet and control and 15% HS diets.

Table 8

Results of Post-Hoc Test for Average Daily Weight Gain of Control and 10% Hempseed (n=32)

	Mean	*df*	*p*	*t*
Control	0.47	30	0.61	0.51
10% Hempseed	0.46			

Table 9

Results of Post-Hoc Test for Average Daily Weight Gain of 10% Hempseed and 15% Hempseed (n=32)

	Mean	*df*	*p*	*t*
10% Hempseed	0.46	29	0.25	1.18
15% Hempseed	0.43			

Table 10

Results of Post-Hoc Test for Average Daily Weight Gain of Control and 15% Hempseed (n=32)

	Mean	*df*	*p*	*t*
Control	0.47	29	0.09	1.71
15% Hempseed	0.43			

Carcass Weight

After processing, the carcass weight of each broiler from each diet group was evaluated. The carcass weights were compared to each other (n = 48). Note the carcasses were disposed of and a meat analysis was not conducted.

The average carcass weights per diet group were: Control 6.30 lbs. (SD = 0.77), 10% Hempseed 5.75 lbs. (SD = 1.15), 15% Hempseed 5.54 lbs. (SD = 0.81). Figure 6 summarizes the carcass weight per broiler diet and Figure 7 expresses the standard deviation error value per diet. The ANOVA analysis resulted with non-statistical significance $F(2, 45) = 2.93$, $p = 0.06$. The ANOVA yielded a medium effect size ($\eta 2$ = 0.12).

Figure 7

Average Carcass Weight Per Diet

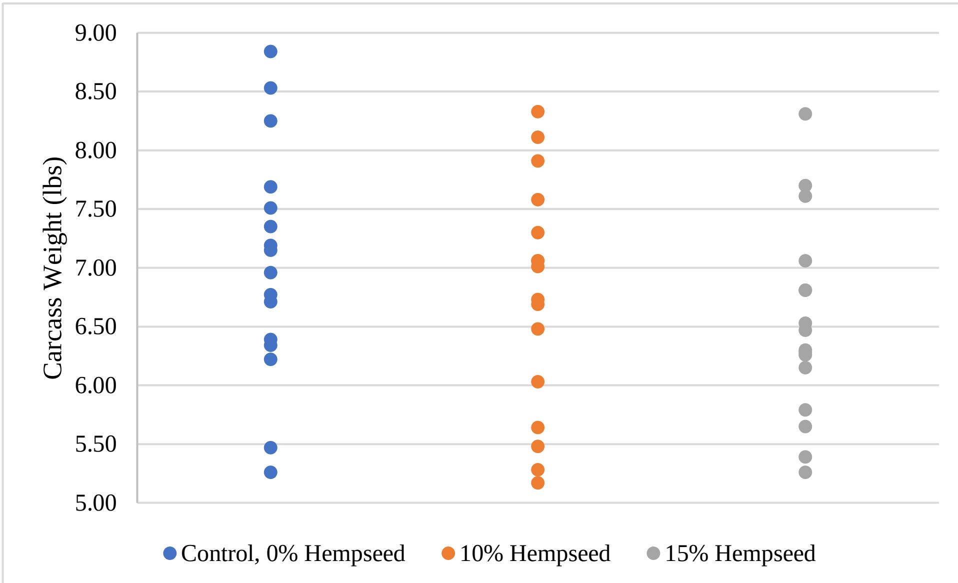
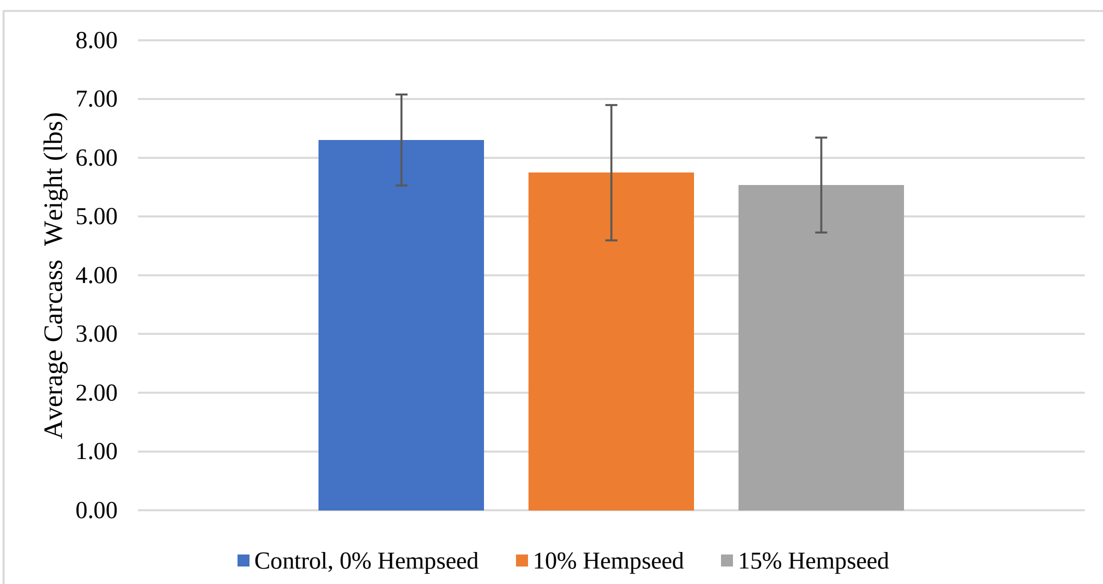


Figure 8

Standard Deviation Error Value of Average Carcass Weight Per Diet



The post-hoc analysis revealed only one statistical significance, Control compared to 15% Hempseed $t(30) = 2.74$, $p < 0.05$. The two other groups were not statistically significant, Control compared to 10% Hempseed $t(26) = 1.61$, $p > 0.05$; 10% Hempseed versus 15% Hempseed $t(27) = 0.60$, $p > 0.05$. Tables 11, 12 and 13 express the post-hoc analysis of the three *t*-tests. The Cohen's D measurement of effect size was large between the control and 10%/15% HS diets, but medium for the 10% and 15% HS diets.

Table 11

Results of Post-Hoc Test for Carcass Weight of Control and 10% Hempseed (n=32)

	Mean	*df*	*p*	*t*
Control	6.30	26	0.12	1.61
10% Hempseed	5.75			

Table 12

Results of Post-Hoc Test for Carcass Weight of 10% Hempseed and 15% Hempseed (n=32)

	Mean	*df*	*p*	*t*
10% Hempseed	5.75	27	0.56	0.60
15% Hempseed	5.54			

Table 13

Results of Post-Hoc Test for Carcass Weight of Control and 15% Hempseed (n=32)

	Mean	*df*	*p*	*t*
Control	6.3	30	0.01	2.74
15% Hempseed	5.54			

Feed Analysis

Samples of each feed and hempseed were sent to Waters Agricultural Lab, Inc. in Owensboro, Kentucky to be evaluated for moisture, crude protein, crude fiber, phosphorus, calcium and total digestible nutrients (TDN). The average of each component is as follows: Moisture 12.77% (SD = 0.81), Crude Protein 19.13% (SD = 2.32), Crude Fiber 11.82% (SD = 14.35), Phosphorus 0.77% (SD = 0.10), Calcium 0.88% (SD = 0.46), TDN 67.63 (SD = 0.42). Table 14 describes the results from the feed analysis.

Table 14

Results from Feed Analysis

	Crushed Hempseed	*Control*	*10% Hempseed*	*15% Hempseed*
Moisture (%)	13.98	12.38	12.42	12.29
Crude Protein (%)	21.24	20.84	18.05	16.37
Crude Fiber (%)	33.18	2.54	4.74	6.83
Phosphorus (%)	0.92	0.72	0.73	0.69
Calcium (%)	0.22	1.17	1.21	0.91
TDN (%)	67.08	68.09	67.78	67.58

Table 15 expresses the nutritional content of the grower concentrate fed to each of the broiler groups. The SBM added in the control and 10% hempseed diets is also noted.

Table 15

Grower Concentrate and Soybean Meal Analysis

	AMT %	ME kcal/g	CP %	Ca %	Tot P %	STTD P %	CF %	F %
Corn (NRC 2012)	50.95	3395	8.24	0.02	0.26	0.09		
SBM (dehulled NRC 2012)	30.00	3294	47.73	0.33	0.71	0.34	<3.5	<50

Note. AMT = amount, ME = metabolizable energy, CP = crude protein, Ca = calcium, Tot P = total phosphorus, STTD P = standardized total-tract digestible phosphorus, CR = crude fiber, F = fat.

Table 16

Selected Nutrient Requirements for Poultry, 2003

Nutrient (percent or unit/kg of diet; 90% dry matter)	Layer 80	Layer 100	Layer 120	Broiler 0-3 wk	Broiler 3-6 wk	Broiler 6-8 wk
Protein, %	18.8	15	12.5	23	20	18
Calcium, %	4.06	3.25	2.71	1	0.9	0.8
Non-phytate phosphorus, %	0.31	0.25	0.21	0.45	0.35	0.3
Potassium, %	0.19	0.15	0.13	0.3	0.3	0.3
Copper, mg/kg	?	?	?	8	8	8
Zinc, mg/kg	44	35	29	40	40	40
Sodium, %	0.19	0.15	0.13	0.2	0.15	0.12

Note. Data for nutrient requirement of poultry from USDA, 2003 retrieved from https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044381.pdf

The following Figures 9-14, reveal the differences of the components from the feed analysis. The hempseed, control, experiment one and experiment two were compared of these nutritional components.

Figure 9

Comparison of Moisture Content

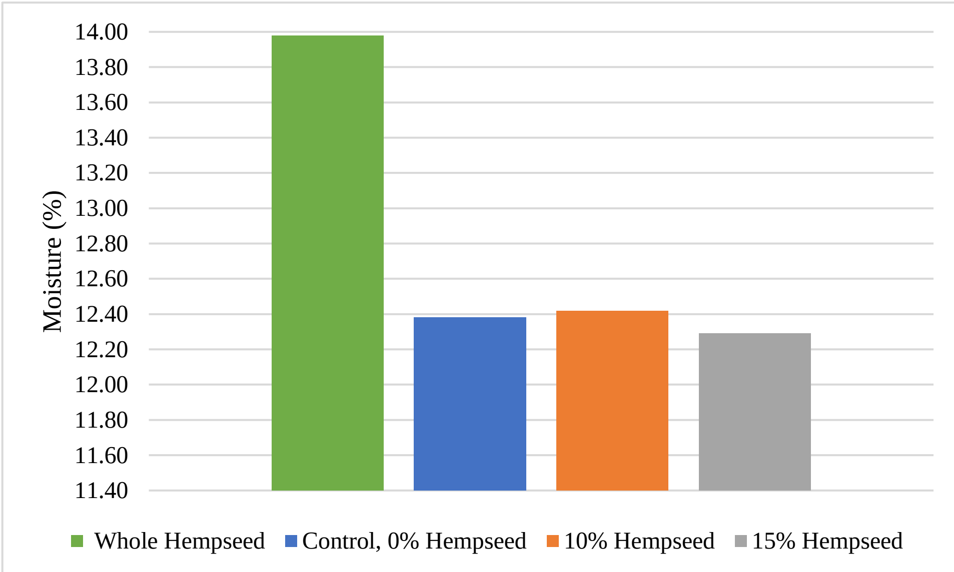


Figure 10

Comparison of Crude Protein

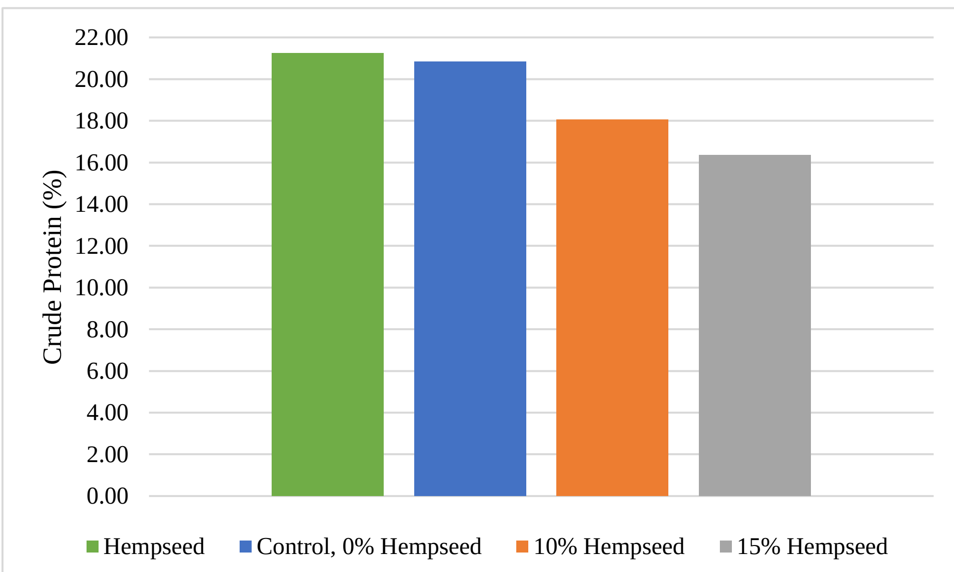


Figure 11

Comparison of Crude Fiber

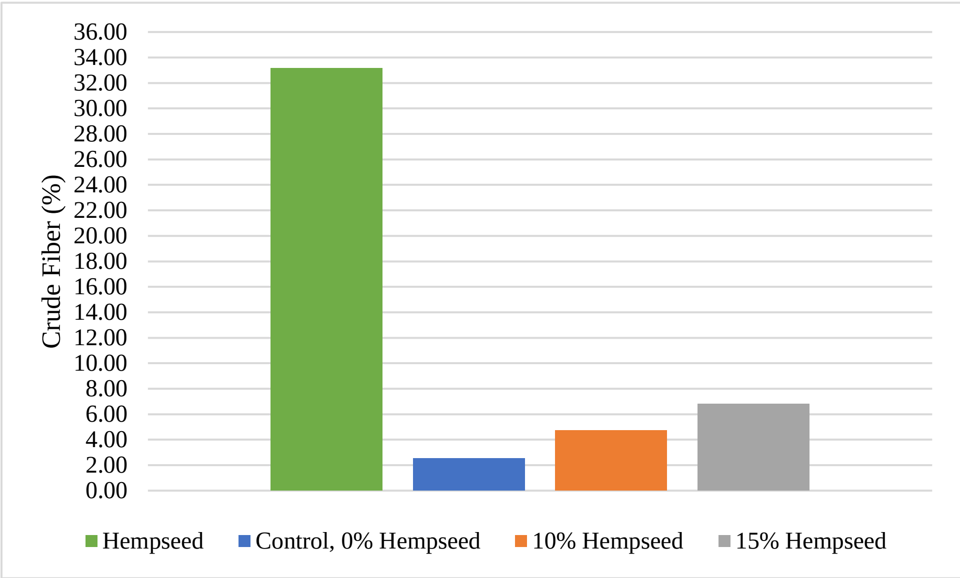


Figure 12

Comparison of Phosphorus

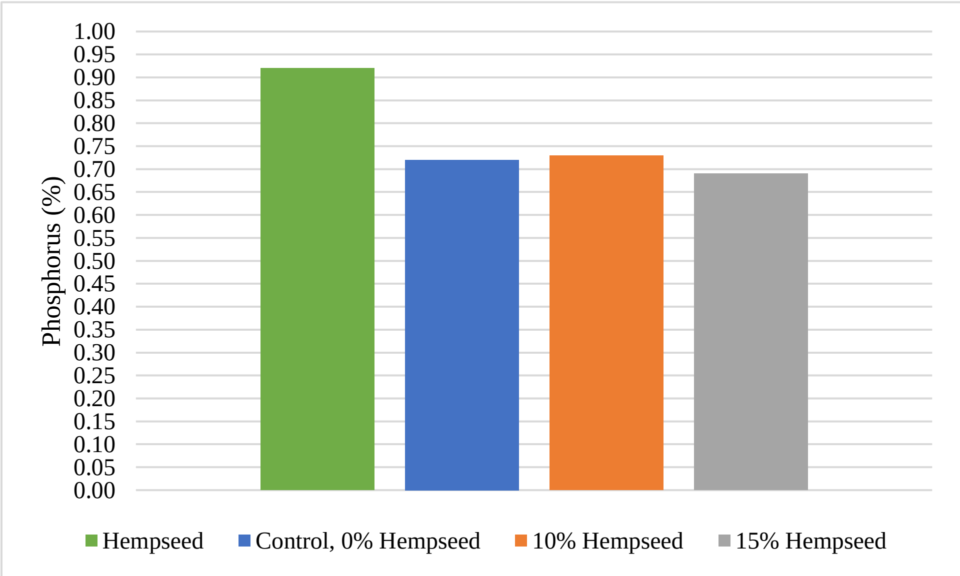


Figure 13

Comparison of Calcium

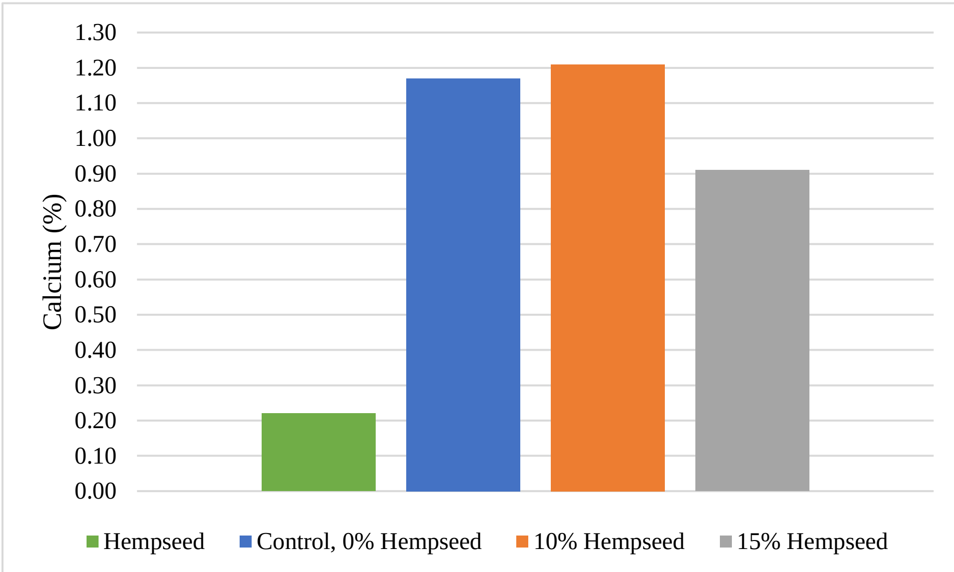
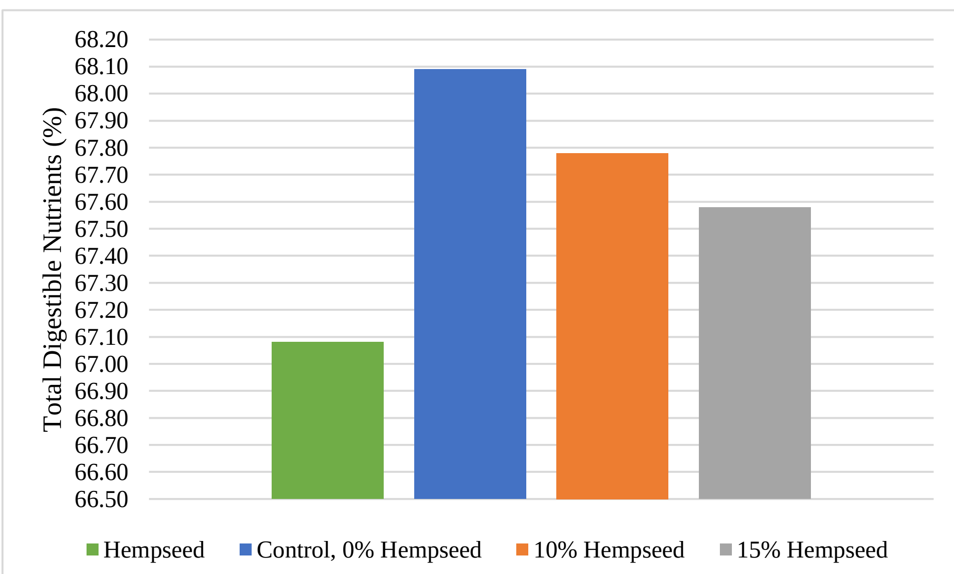


Figure 14

Comparison of Total Digestible Nutrients (TDN)



Conclusion

In conclusion, the analytical results demonstrated a significant difference between the Control and 15% Hempseed diets for FCR and carcass weight. No statistical significance was found for the net weight gain nor average daily weight gain. There were no statistical differences between the Control and 10% Hempseed diets nor between the 10% and 15% Hempseed diets. The effect sizes between the un-significant findings were relatively small or medium, resulting in p-values > 0.05.

Chapter 5

Conclusions and Recommendations

The implementation of hempseed in the broiler chicken diet posed as a potential replacement for soybean meal. With the lack of research and legality, these accusations need to be further investigated. Additionally, existing studies have determined hemp as an adequate supplement for the broiler diet, including a previous broiler study performed at Murray State University, utilizing hemp hearts. Contrarily, this research study resulted in a significant finding that the hempseed-added diets did not provide an increase in growth nor final weight compared to a single soy-based diet. This chapter discusses the results from this research study. Additionally, recommendations for future research including broiler nutrition, housing and study improvements are included.

Broiler Net Weight Gain

During this study, the broilers were weighed once a week. The results show that the Control diet had a variety of weights, the maximum weight being 7.86 lbs. and the minimum weight was 4.56 lbs. The control compared to the 10% hempseed diet determined the control had a larger net weight average. Next, the 10% and 15% hempseed diets were compared, resulting with the 10% diet with a higher average net weight gain. Finally, the control and 15% hempseed diets were compared, much like how the others resulted, the control had a larger net weight gain average. The ANOVA and post-hoc results determined the net weight gain was not significant between any of the diets. The effect size from the ANOVA determined 6% of the variance of weight gain was due to diet. This may have been due to each group was within the overall average weight gain at 5.96 lbs. As seen in Figure 1, the outstanding broiler weights, such as the largest of the control diet, may have been a larger bird to begin with. However, when reviewing Figure 2, the standard deviation error for the 15% hempseed diet is far less than the control and 10% hempseed diets. This could be because the 15% hempseed diet did not contain SBM, resulting in less protein. The feed analysis reflected this finding.

Feed Conversion Ratio

Each individual broiler was fed a pre-determined amount of feed per day. Leftover feed was measured and recorded every 24 hours. The feed conversion ratio was determined by feed consumption and net weight gain in pounds. The lower the FCR, the better feed efficiency, or the less amount of feed consumed. Overall, the 15% hempseed diet had the highest FCR, meaning the group consumed more feed but gained less weight. The control diet had the lowest FCR and ate less feed, but gained more weight. The standard deviation error was very large for the FCRs of each diet group. However, the control and 15% hempseed diets were statistically different with a large effect size. This meaning there was a difference between the control and 15% hempseed diets. These results make sense as they are depicted in the feed analysis. The crude fiber content of the 15% hempseed was very large at 6.83% compared to the control at 2.54%. This determines the FCR for the 15% hempseed was due to the high increase of crude fiber in the diet and less protein, resulting in the broilers eating higher amounts of feed. This result also determines that the 15% hempseed was a lower quality feed for broiler performance. The large effect size from the ANOVA analysis determined there is a 16% chance the FCR was due to diet.

Average Daily Weight Gain

Similar to the trend of the average net weight gain, the average daily weight gain resulted in the control diet having the largest weight and the 15% hempseed diet with the lowest weight. The ANOVA and post-hoc analysis did not show a statistical significance between any diet group. The ADWG for each diet group was similar with an overall average of 6.77 lbs. and the standard deviations were close in number. There was a 30% variation of weight gain due to diet determined by the large effect size. The ADWG was also affected by the HS diets, as those diets gained the least amount of weight. As stated previously, the feed analysis represents this trend due to the crude fiber and crude protein content differences between the control and HS diets.

Carcass Yield

Unlike the other weight determining factors, the average carcass yield per diet showed a significant difference between the control and 15% HS diets. The average carcass weights are summarized in Table 13 and had a large effect size, which. There was roughly an average pound difference between the control and 15% HS diets. This may be explained by the amount of fat percentage on the 15% HS diet broilers than the control diet due to the amount of protein from the consumed. Also, the 10% HS diet had a larger error value than either of the other diets, which contributes to the variation of the carcass yield. The overall effect size was large with a 12% variation due to diet.

Feed Analysis

As seen in Table 14, the differences between the crushed hempseed and the feeds, control, 10% HS and 15% HS are important to determine how the broilers were affected by their diet. The whole, crushed HS had a 21.24% of crude protein, which deterred down the line of feeds, the 15% HS diet having the lowest amount. The HS crude fiber content was exceptionally large at 33.18%, which increased between the feeds, the 15% HS diet consisting of only 6.83%. The phosphorus was the highest in the HS at 0.92%, but the 10% HS diet had the highest between the feeds. The phosphorous content in the 10% HS diet may have been higher since there were both SBM and HS added. Contrarily, the HS had a low amount of calcium (0.22%), where the 10% HS diet had the highest amount at 1.21%. This increase in calcium may also be due to the fact there were both SBM and HS added to the diet. However, the control had the highest total digestible nutrients at 68.09%, but the other feeds and HS were only 1% away. The added HS may have reduced the digestibility for the other two diets, as the control contained no hempseed.

Overall, the crushed, whole hempseed had the largest percentage of moisture content, crude fiber, crude protein and phosphorus. Additionally, the crushed, whole hempseed had the least percentage of calcium and TDN. The 15% hempseed diet had the least amount of moisture, crude protein and phosphorus. These results strengthen the evidence that the hempseed diets were not adequate for broiler growth. This is potentially due to the amount of hempseed added to the diets, either too little or too much. Note, there was a significant amount of crude fiber in the hempseed, which led to the broilers consuming more feed. This lower protein diet may have increased carcass fat deposition and use of energy. In contrast, the control diet had a higher amount of protein, leading to a lower FCR, higher overall growth and carcass yield. The reason being the increase of protein improves carcass yield, quality and ADWG by also reducing abdominal fat (Fouad & El-Senousey, 2014).

Recommendations for Future Research

To optimize results, it is recommended to utilize a free-range industry standard broiler house, albeit on a smaller scale. Also, automatic waterers should be installed for more efficient water use and ease of care. For the best statistical significant results, the study size should be up to 66 broilers. Also, an industry representative or veterinarian for broilers (such as Perdue Farms or Pilgrim's Pride) should be a part of planning the research study. This will entail industry recommendations are followed and broilers are managed and housed properly.

Furthermore, if utilizing crushed, whole hempseed, correct calculations should be conducted to determine adequate protein and substitution of other protein sources. Ideally, protein intake will be the same amount for each diet. If hempseed is not available, hemp byproducts should be used to help hemp processors find a new market and to determine if the byproducts are useful for broiler nutrition. Additional diets should be added with higher percentages of hempseed; potentially five different diets to determine if any nutrients are lacking or need to be substituted. Example: control, 5%, 15%, 25%, 50% hempseed replacement. Also, the hemp additive needs to be the same consistency as the industry feed crumble to prevent broilers from picking around the hemp.

In addition, a meat analysis should be conducted at the conclusion of the study. Fat pads should be harvested and labeled to be analyzed for: protein, omega-3, omega-6, iron, hormone levels, density/weight, full nutritional panel and THC. Any broilers with poor performance, FCR and weight gain should be euthanized at the conclusion of the study for a necropsy to determine the underlying cause.

Recommendations for Practitioners

A commercial broiler breed should be used for future research, such as in this one, Ross 708, which is known for fast growth. Broiler chicks should be bought as one day old chicks to factor out any previous health issues. The chicks should be vaccinated against Newcastle Disease, Marek's Disease, Coccidiosis and infections bronchitis to prevent any development of disease. The study should be conducted for at least six weeks in a broiler house to mimic industry standards.

Additionally, utilizing other hemp forms will provide a variety of research to determine the best hemp product for broiler growth. This may include hemp cake, hemp byproducts, hemp oil and hemp hearts.

Conclusion

Data from this study signifies the hempseed substitution percentages utilized were not adequate for efficient broiler performance. The two hempseed diets had a poorer growth rate, feed conversion and carcass yield than the control. The determining factors were the protein levels were not adequate and the crude fiber of the hempseed was too high. However, the broilers did have a palate for the hempseed and no mortalities were accounted for.

During this study, the feed conversion and weight gain were similar between the control and 10% hempseed diets. The control and 15% hempseed diets were significant for feed conversion and carcass yield. This suggests utilizing hempseed as a feed replacement for broiler chickens could potentially deter performance. Moreover, nutrients for broiler nutrition is important for optimal growth and performance and correctly providing the right amount of nutrients is essential.

References

AAFCO. (2019). AAFCO guidelines on hemp in animal food. *Changes to Hemp Production in the 2018 Farm Bill, (10113-10114),* 429-435. Retrieved from September 15, 2019, from https://www.aafco.org/Portals/0/SiteContent/Announcements/Guidelines_on_Hemp_in_Animal_Food_May_1_2019.pdf

Aggrey, S. E., Karnuah, A. B., Sebastian, B., & Anthony, N. B. (2010). Genetic properties of feed efficiency parameters in meat-type chickens. *Genetics Selection Evolution*, *42*(1). doi: 10.1186/1297-9686-42-25

Baker, K. M., Utterback, P. L., Parsons, C. M., & Stein, H. H. (2011). Nutritional value of soybean meal produced from conventional, high-protein, or low-oligosaccharide varieties of soybeans and fed to broiler chicks. *Poultry Science, 90*(2), 390–395. DOI: 10.3382/ps.2010-00978

Beski, S. S, Swick, R. A., & Iji, P.A. (2015). Specialized protein products in broiler chicken nutrition: a review. *Animal Nutrition,* 1(2), 47-53. DOI:10.1016/j.aninu.2015.05.005

Calloway, J. C. (2004). Hempseed as a nutritional resource: an overview. *Euphytica, 140*(1-2),65-72. DOI: 10.1007/s10681-004-4811-6

Crescente, G., Piccolella, S., Esposito, A., Scognamiglio, M., Fiorentino, A., & Pacifico, S. (2018). Chemical composition and nutraceutical properties of hempseed: an ancient food with actual functional value. *Phytochemistry Reviews, 17*(4), 733–749. DOI: 10.1007/s11101-018-9556-2

Edris, A. M., Hemmat, M. I., Shaltout, F. A., Elshater, M. A., & Eman, F. M. I. (2012).

Chemical analysis of chicken meat in relation to its quality. *Benha Veterinary Medical Journal*, *23*(1), 87–93.

EFSA. (2011). Scientific Opinion on the safety of hemp (cannabis genus) for use as animal feed. *EFSA Journal*, 9(3). DOI: 10.2903/j.efsa.2011.2011

Erdaw, M. M., Perez-Maldonado, R. A., & Iji, P. A. (2017). Physiological and health-related response of broiler chickens fed diets containing raw, full-fat soya bean meal supplemented with microbial protease. *Journal of Animal Physiology and Animal Nutrition*, *102*(2), 533–544. DOI: 10.1111/jpn.12785

Febles, E., CRD NC State Extension, & Edmisten, K. (n.d.). NCSU researcher wrap-up initial hemp in animal feed trial. Retrieved September 2019 from https://industrialhemp.ces.ncsu.edu/2018/02/ncsu-wraps-up-hemp-animal-feed-trial/

Fouad, A. M., & El-Senousey, H. K. (2014). Nutritional factors affecting abdominal fat deposition in poultry: a review. *Asian-Australasian Journal of Animal Sciences*, *27*(7), 1057–1068. DOI: 10.5713/ajas.2013.13702

Gakhar, N., Goldberg, E., Jing, M., Gibson, R., & House, J. D. (2012). Effect of feeding hempseed and hempseed oil on laying hen performance and egg yolk fatty acid content: Evidence of their safety and efficacy for laying hen diets. *Poultry Science, 91*(3), 701–711. DOI: 10.3382/ps.2011-01825

Hooks, C., Parr, B., Brannon, T., Chae, H., & Snider, M. (2020). Effects of using hemp hearts as a feed additive in broiler chicks. *Journal of Agricultural Hemp Research*. [Unpublished] Retrieved from https://digitalcommons.murraystate.edu/jahr

Khan, R. U., Durrani, F. R., Chand, N., & Anwar, H. (2010). Influence of feed supplementation with *Cannabis Sativa* on quality of broilers carcass. *Pakistan Veterinary Journal*, *30*(1), 34–38. DOI: 2074-7764

Khoddami, A., Chrystal, P. V., Selle, P. H., & Liu, S. Y. (2018). Dietary starch to lipid ratios influence growth performance, nutrient utilization and carcass traits in broiler chickens offered diets with different energy densities. *Plos One*, *13*(10). DOI: 10.1371/journal.pone.0205272

Leeson, S., & Zubair, A. (1997). Nutrition of the broiler chicken around the period of compensatory growth. *Poultry Science*, *76*(7), 992–999. DOI:10.1093/ps/76.7.992

Leizer, C., Ribnicky, D., Poulev, A., Dushenkov, S., & Raskin, I. (2000). The composition of hempseed oil and its potential as an important source of nutrition. *Journal of Nutraceuticals, Functional & Medical Foods*, *2*(4), 35–53. DOI: 10.1300/j133v02n04_04

Mateos, G., Jiménez-Moreno, E., Serrano, M., & Lázaro, R. (2012). Poultry response to high levels of dietary fiber sources varying in physical and chemical characteristics. *Journal of Applied Poultry Research*, *21*(1), 156–174. DOI: 10.3382/japr.2011-00477

Milanković, B., Ćirić, J., Krstić, M., Starčević, M., Baltić, B., Šefer, D., … Marković, R. (2019). Effect of dietary fatty acid pattern on growth performance, carcass characteristics, fatty acid profile, and serum biochemistry parameters in broiler chickens. *Kafkas Universitesi Veteriner Fakultesi Dergisi*. DOI: 10.9775/kvfd.2018.21205

Mir, N. A., Tyagi, P. K., Biswas, A. K., Tyagi, P. K., Mandal, A. B., Kumar, F., …

Verma, A. K. (2018). Inclusion of flaxseed, broken rice, and distillers dried grains with solubles (DDGS) in broiler chicken ration alters the fatty acid profile, oxidative stability, and other functional properties of meat. *European Journal of Lipid Science and Technology*, *120*(6), 1700470. DOI: 10.1002/ejlt.201700470

Murakami, A. E., Oviedo-Rondon, E. O., Martins, E. N., Pereira, M. S., & Scapinello, C. (2001). Sodium and chloride requirements of growing broiler chickens (twenty-one to forty-two days of age) fed corn-soybean diets. *Poultry Science*, *80*(3), 289–294. DOI:10.1093/ps/80.3.289

Ondrej, S., Filip, K., Hana, S., Vaclav, T., Tomas, V., Leos, P., & Eva, M. (2015). The effect of hempseed cakes on broiler chicken's performance parameters. *Mendel Net*, 157–160. Retrieved September 2019 from https://mnet.mendelu.cz/mendelnet2015/articles/60_stastnik_1094.pdf?id=1094&file=60_stastnik_1094.pdf

Pesti, G. M., Bakalli, R. I., Qiao, M., & Sterling, K. G. (2002). A comparison of eight grades of fat as broiler feed ingredients. *Poultry Science*, *81*(3), 382–390. DOI: 10.1093/ps/81.3.382

Petracci, M., Mazzoni, M., Meluzzi, A., & Sirri, F. (2013). Comparison of breast muscle traits and meat quality characteristics in 2 commercial chicken hybrids. *Poultry Science, 92*(9), 2438–2447. DOI:10.3382/ps.2013-03087

Punda, I., & Prikhodko, D. (2010). Poultry meat & eggs agribusiness handbook. Retrieved September 2019 from http://www.eastagri.org/publications/pub_docs/6_Poultry_web.pdf.

Silversides, F.G., K.L. Budgell & M.R. Lefrançois, 2002. Effect of feeding hemp seed meal to laying hens. *Atlantic Poultry Research Institute*; APRI Factsheet 16(2). Retrieved October 1, 2019, from https://cdn.dal.ca/content/dam/dalhousie/pdf/sites/apri/Effect of Feeding Hemp Seed Meal to Laying Hens.pdf

Silversides, F., & Lefrançois, M. (2005). The effect of feeding hemp seed meal to laying hens. *British Poultry Science*, *46*(2), 231–235. DOI: 10.1080/00071660500066183

Skinner-Noble, D., & Teeter, R. (2003). Components of feed efficiency in broiler breeding stock: energetics, performance, carcass composition, metabolism, and body temperature. *Poultry Science*, *82*(7), 1080–1090. DOI: 10.1093/ps/82.7.1080

Šťastník, O., Jůzl, M., Karásek, F., Fernandová, D., Mrkvicová, E., Pavlata, L., … Doležal, P. (2019). The effect of hempseed expellers on selected quality indicators of broiler chicken's meat. *Acta Veterinaria Brno*, *88*(1), 121–128. DOI:10.2754/avb201988010121

USDA. (2003). Nutrient management technical note no. 4: feed and animal management for poultry. 2. Retrieved March 15, 2020, from https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044381.pdf

USDA. (2013). Poultry industry manual. Retrieved September 20, 2019, from https://www.aphis.usda.gov/animal_health/emergency_management/downloads/documents_manuals/poultry_ind_manual.pdf

U.S. Poultry & Egg Association. (2018). Chicken feeds America. Retrieved October 1, 2019, from https://www.chickenfeedsamerica.org/

Vispute, M. M., Sharma, D., Mandal, A. B., Rokade, J. J., Tyagi, P. K., & Yadav, A. S.

(2019). Effect of dietary supplementation of hemp (Cannabis sativa) and dill seed (Anethum graveolens) on performance, serum biochemicals and gut health of broiler chickens. *Journal of Animal Physiology and Animal Nutrition*, *103*(2), 525–533. DOI: 10.1111/jpn.13052

Wang, X.-S., Tang, C.-H., Yang, X.-Q., & Gao, W.-R. (2008). Characterization, amino acid composition and in vitro digestibility of hemp (Cannabis sativa L.) proteins. *Food Chemistry*, *107*(1), 11–18. DOI: 10.1016/j.foodchem.2007.06.064

Willems, O., Miller, S., & Wood, B. (2013). Aspects of selection for feed efficiency in meat producing poultry. *Worlds Poultry Science Journal*, *69*(1), 77–88. DOI: 10.1017/s004393391300007x

Appendix A

IACUC Application and Approval

MURRAY STATE
UNIVERSITY

Institutional Animal Care and Use Committee

328 Wells Hall
Murray, KY 42071-2393
270-809-3534 • 270-809-3535 fax

May 13, 2019

Brian Parr
Animal Health Technology
Murray State University
Agriculture Sciences
213 South Oakley Applied Science
Murray, KY 42071

Dear Dr. Parr:

The Murray State University Institutional Animal Care and Use Committee (IACUC) has approved your research protocol for the project titled, "Feeding Hemp Products to Poultry."

The research protocol timeline is approved through August 31, 2020. Please use the Animal Use Report (attached) to keep up-to-date information about the animals. At the termination of the protocol, you will need to complete the Conclusion Report (attached) and list final information concerning the animals.

If you have any questions, please contact me at 270-809-3534.

Sincerely,

Kristi Stockdale
IACUC Coordinator

cc:
IACUC File

murraystate.edu