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Evaluation of Supplementing Whole Cottonseed within Feedlot Rations during the Stockerphase of Production with the Goal of Increasing Average Daily Gain

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EVALUATION OF SUPPLEMENTING WHOLE COTTONSEED WITHIN FEEDLOT RATIONS DURING THE STOCKER PHASE OF PRODUCTION WITH THE GOAL OF INCREASING AVERAGE DAILY GAIN

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I dedicate this thesis to my parents Scott and Ellie Cook, who have helped to provide my education over the years. Also, I dedicate this work to my sister and her husband Haley and Corey Courtney, who have constantly encouraged and provided laughter during my two years at Western. Lastly, I would like to dedicate my work to my boyfriend Ian Handley, who stood by my side every step of the way.

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EVALUATION OF SUPPLEMENTING WHOLE COTTONSEED WITHIN FEEDLOT RATIONS DURING THE STOCKER PHASE OF PRODUCTION WITH THE GOAL OF INCREASING AVERAGE DAILY GAIN

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Beef calves are weaned at 6-months of age and enter the stocker phase of beef production. Stocker producers have the primary goal of adding weight inexpensively to increase profit on weaned calves. Whole cottonseed is an inexpensive feed ingredient that is popularly top-dressed within dairy and finishing beef diets and is high in protein and energy. During three periods lasting 50-days (fall 2019, fall 2020, and spring 2020), freshly weaned calves were placed on a finishing ration with the goal of increasing average daily gain. Base rations were calculated at 25% tall fescue hay, 23% corn, and 52% distillers' solubles. Calves were randomly assigned to two treatment groups: one consisting of the base ration and the second consisting of the base ration plus an additional 1% of whole cottonseed. All three periods found that the first 25-days showed a trend for calves fed whole cottonseed to have higher average daily gain during the first 25-days ($P < 0.05$) compared to calves on the control ration. Average daily gain between all three periods did not show significant variations between treatment groups ($P = 0.2$). Whole cottonseed did show positive trends of increasing total weight gain throughout the three periods compared to the control diet. Thus, adding whole cottonseed to the diet of weaned calves can potentially increase average daily gain specifically during the first 25-days on a finishing diet.

INTRODUCTION

Beef cattle producers are always searching for inexpensive alternatives for additional weight gain to beef animals before they head to market. Profitability is important in beef production. Producers are constantly looking for a way to realize large gains without sacrificing profit. This is especially important during the stocker phase of production, where producers buy or raise calves as cheaply as possible to obtain a large return on their investment. The stockering phase of production begins when weaning is complete, and the calves are separated into a drylot or pasture. This phase of beef production usually lasts 6-months with the goal of increasing growth and weight gain. Producers have a goal of completing this phase of production as inexpensively as they can to improve profit. Profitability of the stocker phase of production is usually dependent upon inexpensive feed ingredients and forage management.

Feedlot rations are formulated with the goal of increasing grain intake in growing calves without sacrificing the forage quality of the pastures. Calves are removed from their dams at 6-months of age and immediately weaned into a drylot or pasture to grow and increase weight gain before being sold into market for finishing and slaughter. Feedlot rations are utilized for growing or finishing beef cattle. These rations focus on a high grain diet with roughages added into the mix (Lalman and Sewell, 1993). High grain diets can help increase energy and protein contents and are less expensive and allow for pastures to recover (Lalman and Sewell, 1993). In feedlot rations, efficiency increases when the ration supplies larger amounts of energy compared to the body weight of the calf (Lalman and Sewell, 1993). Growing calves on high energy diets will result in faster weight gain and require less feed energy per pound of gain (Lalman and Sewell, 1993).

These high energy grain diets are less expensive to feed daily and are generally fed to growing or finishing calves.

Whole cottonseed has become a popular feed ingredient within dairy and beef rations for its inexpensive price and high protein and energy content. Cottonseed has become highly available in the southern United States creating interest among beef producers to include whole cottonseed within their beef rations (Myer and Hersom, 2018). Whole cottonseed is high in energy, protein, total digestible nutrients (TDN), fiber, and phosphorus. Cottonseed also contains a high lipid content resulting in higher TDN (Myer and Hersom, 2018). Since whole cottonseed has such a high lipid content, cottonseed should not be supplied within the diet more than 0.5% per body weight in mature cows and no more than 0.33% per body weight in weaned calves (Myer and Hersom, 2018). Whole cottonseed can be fed without any feed processing and is typically top dressed into finishing rations. Unfortunately, whole cottonseed is not very palatable and can take time for weaned calves or mature cattle to readily consume cottonseed. Whole cottonseed also contains free gossypol which is toxic to most livestock species. Within the beef production system, gossypol is only a concern when feeding whole cottonseed to young calves and breeding bulls. Gossypol toxicity can interfere with male fertility and should only be fed in small amounts (Myer and Hersom, 2018). Whole cottonseed should be stored in a dry and moisture free environment to prevent mold formation and reduction in palatability. Since whole cottonseed is readily available and inexpensive, beef producers are beginning to feed cottonseed within their finishing diets more frequently. If fed properly, whole cottonseed can add energy and protein within growing cattle and promote increased weight gain and higher average daily gains.

LIT REVIEW

Cotton

Overview

Within the United States, there are vast agriculture industries created for utilization and advancements in animal agriculture and nutrition. One of these industries focuses solely on cottonseed, contained within the fruit of the cotton plant. The processing and refinement of cottonseeds is a major agriculture industry within the United States responsible for creating cottonseed oil and other cottonseed by-products (Adam and Geissman,1960). Cottonseed oil is utilized for human and animal consumption, or even fertilizer (Adam and Geissman, 1960). Cotton plants produce a toxin called, “Gossypol” which is a natural phenolic compound (Gadelha et al., 2014). This toxin is produced by pigment glands in cotton stems, leaves, seeds, and flower buds (Gadelha et al., 2014). Cottonseeds are commonly fed in the animal agriculture industry for their high protein content. The toxin embedded in the cottonseeds limits the amount of daily utilization in animal feeds. If fed at high amounts, gossypol can cause respiratory distress, impaired weight gain, anorexia, weakness, apathy, and death in extreme cases (Gadelha et al., 2014). Gossypol can also cause impairments to male and female reproductive tracts (Gadelha et al., 2014). In some cases, high levels of gossypol can interfere with an animal’s immune system leading to infection susceptibility and decreases in vaccine efficiency. Treating and processing cottonseeds with heat can decrease the toxic amounts of gossypol bound within the cottonseed (Gadelha et al., 2014). Preventative procedures limiting toxicity levels within the cottonseed allows for reductions in toxicity levels and higher amounts that can be fed to animals. Cottonseed is a cheap, high fiber ingredient formulated in animal feeds to increase protein content inexpensively (Adam and Geissman, 1960).

Cotton Industry

Cotton (*Gossypium* spp.) comes from the Malvaceae family and is known to be one of the earliest plants utilized by man (Gadelha et al., 2014). Cotton is primarily cultivated for fiber and the oil from the cottonseeds. Cotton is considered an arborous plant and has been employed by mankind for thousands of years and are primarily utilized in the textile industry (Gadelha et al., 2014). Fiber and oil produced from cotton plants generate by-products rich in fat from oil and protein that are used in animal feeding (Gadelha et al., 2014). Cotton is grown extensively within the United States and has the potential to increase the world's food supply through the production and utilization of cotton by-products. Cottonseeds are inexpensive and nutritionally, cotton by-products compare highly to other vegetable and animal protein sources (Alford et al., 1996; Table 1). Cottonseed has been shown through previous research to increase weight gain, promote daily growth and a positive nitrogen balance (Alford et al., 1996). For every 230 kgs of cotton fiber produced, there has been shown to be 75-100 kgs of cottonseed protein produced (Alford et al., 1996). The protein produced from cottonseeds contains a healthy ratio of amino acids, including lysine, threonine, methionine, and isoleucine. Compared with other vegetable and animal protein sources, cottonseed contains a lower fat content and significantly higher amount of protein, over 24% on a DM basis (Alford et al., 1996). Cottonseed creates by-products rich in protein and lower in fat content that can been successfully used in human and animal nutrition studies.

Thus, cottonseed has the potential to increase growth and weight gain in finishing beef diets.

Nutrient Content

Table 1. Nutrient Content of Whole Cottonseed (NRC, 2016)

Component	Amount
DM (%AF)	92.63 ± 2.10 (529)
Ash (% DM)	7.53 ± 1.76 (549)
TDN (% DM)	93.0
ME (Mcal/kg)	3.36
Fat (% DM)	19.45 ± 2.59 (534)
NDF (% DM)	47.82 ± 6.96 (192)
ADF (% DM)	42.85 ± 5.80 (90)
CP (% DM)	22.87 ± 2.53 (536)
Ca (% DM)	0.22 ± 18.48 (165)
P (% DM)	0.53 ± 0.09 (94)
K (% DM)	1.12 ± 0.14 (57)

Gossypol Toxicity

Gossypol is a phenolic toxic compound that is produced by cotton plants. The name, "gossypol" is derived from the plant genus scientific name (*Gossypium*) combined with the ending of "ol" from phenol (Gadelha et al., 2014). Gossypol is considered toxic for animal consumption, has yellow pigmentation and is insoluble in water (Gadelha et al., 2014). Gossypol is produced through pigmented glands in cotton stems, leaves, seeds, and buds (Gadelha et al., 2014). Black spots distributed all over the cotton plant are the location of the pigmented glands. The highest concentration of gossypol is located within the cottonseeds (Gadelha et al., 2014). Each cottonseed may contain up to 35 grams of gossypol/kg (Gadelha et al., 2014). Gossypol has several toxic effects but has been known to repel pests within the cotton plant. With all the negativity surrounding gossypol, there is also potential for this toxin to possess therapeutic properties. Compounds associated with the toxin have been shown to fight against certain pathogens and viruses such as influenza, bacterial and yeast infections, possible treatments for leukemia, colon carcinoma, breast cancer, and other diseases (Gadelha et al., 2014).

Gossypol has different absorption rates within the digestive tract with relation to the amount of iron consumed within the diet. In ruminant species, microbial fermentation in the rumen binds free gossypol toxins with proteins (Gadelha et al., 2014). This absorbed gossypol accumulates in the liver and kidneys. Gossypol is excreted through bile and is eliminated through feces (Gadelha et al., 2014). Young ruminants are more sensitive to gossypol concentrations than adult animals since gossypol is not bound during ruminal fermentation and only occurs in animals with fully functioning rumens (Gadelha et al., 2014). Acute toxicity can occur if cottonseed is not fed properly. Liver damage, respiratory distress, and reproductive effects are largely seen in acute toxicity of gossypol (Gadelha et al., 2014). Preventative procedures help to decrease concentrations within cotton by-products. Decreasing gossypol concentrations can help decrease the chances of acute toxicity. Through heat and pressure, gossypol concentrations can be reduced in cotton by-products to allow feeding to animals at a safe level (Gadelha et al., 2014). Through genetic selection, geneticists have helped to create cotton varieties devoid of the pigmented glands that produce gossypol (Gadelha et al., 2014). Maximum free gossypol concentrations for cottonseed are 5,000 ppm and 1,200 ppm for cottonseed meal and cake, respectively (Gadelha et al., 2014). For complete feeding, cattle, sheep, and goats can receive up to 500 ppm of gossypol within their diet (Gadelha et al., 2014). Feeding the accurate daily intake of unprocessed cottonseed can be done without harm to the animal. Unprocessed cottonseed should not be fed above 0.5% body weight (BW) per head per day (Gadelha et al., 2014). Cottonseed is a great source of protein and energy for cattle and is economically friendly to feed to cattle to increase weight gain without spending large amounts of money.

Even though whole cottonseed contains varying amounts of gossypol, if fed properly cottonseed can increase growth rates and weight gains within the desired animal. Cottonseed protein has also been shown to support bone growth and development (Alford et al., 1996). Animals fed 9 and 18% calories from protein containing 0, 50, or 100% cottonseed protein displayed an increase in calcium content within the bones as the rate of cottonseed supplementation increased (Alford et al., 1996). This increase in calcium content is important in young or growing animals. Cottonseed also contains zinc and phytic acid. Animals that are fed cottonseed are consuming zinc directly which can result in higher average weight gain (Alford et al., 1996). Cotton processing results in a wide variety of by-products that can be utilized within human and animal nutrition. The processing of cottonseeds produces by-products rich in fat and protein. The by-products commonly used in animal nutrition are linted cottonseed, cottonseed hulls, cotton linters, cottonseed meal, and cottonseed oil (Roger et al., 2002). Whole cottonseed is a good source of protein, energy and phosphorous. Whole cottonseed is primarily used in the dairy industry as an additional protein source for the cows. Cottonseed is a cheap feed ingredient that has shown improved growth and gain within cattle. The average annual harvested cotton U.S. acreage from 1991 to 2000 was over 5.3 million hectares (Roger et al., 2002). These 5.3 million hectares produced 7.7 billion kgs of cottonseed between 1991 and 2000 (Roger et al., 2002). Whole cottonseed is an ideal supplement for brood cows because of the high protein and energy content that tends to be deficient in many lactating diets. The crude protein content in cottonseed is classified as a true protein

(Roger et al., 2002). True protein sources are better for supplementing high-forage diets compared with non-protein nitrogen (Roger et al., 2002). Protein within the hulls is combined with the fat and provides a slow release within the rumen. If fed properly, cottonseed will not interfere with forage digestion (Roger et al., 2002). The fat content within cottonseeds has been shown to improve cattle reproductive performance, especially within thin cows (Roger et al., 2002). Whole cottonseed fat has the potential to reduce metabolic heat production making cottonseed extremely valuable during the summer months (Roger et al., 2002). A major advantage to feeding cottonseed to cattle, is that they can consume the cottonseeds whole. Whole cottonseeds should be fed in feed bunks and kept dry to increase palatability (Roger et al., 2002). Whole cottonseed has a high fat content; thus, intake should be limited to 0.5% of body weight per day or 20% of the diet (Roger et al., 2002). Whole cottonseed fed at 0.5% of the cow's body weight can provide 4% fat to the total ration (Roger et al., 2002). Properly feeding whole cottonseed is key to reducing and preventing the effects of gossypol from within the whole cottonseed.

Animal Performance

Feeding whole cottonseed to cattle can be very beneficial and cost efficient within a beef operation without spending large amounts of money. Whole cottonseed can be top dressed or mixed within a ration but should be fed at no more than 0.5% mature body weight daily to ensure there are no issues with gossypol toxicosis (Roger et al., 2002). Producers feeding whole cottonseed in a cow/calf operation need to be careful to not overfeed bulls, developing heifers, and preruminant calves to protect them from the potential toxic effects of gossypol (Rogers et al., 2002). If fed properly, gossypol toxicity can be prevented and whole cottonseed can be a great source of protein for cattle. For growing cattle, 0.33% body weight daily is the recommended consumption rate of cottonseed daily (Roger et al., 2002). Feeding whole cottonseed at higher amounts to growing cattle has the potential of producing negative effects from gossypol. Bulls should be fed at the same 0.33% bodyweight as growing cattle (Roger et al., 2002). Preruminant cattle should consume very low amounts of cottonseed daily as the risk is greater for gossypol toxicity in younger cattle with developing rumens. Thus mature, growing cattle, and bulls should consume whole cottonseed at no more then 15-20% of total diet. Cottonseed is an inexpensive source of energy, fiber, and protein for cattle. If fed at these recommended daily intakes, whole cottonseed can increase weight gain, promote growth, and improve overall health of the cattle.

In a 2019 study conducted at the Universidade de São Paulo in Brasil, Noguiera et al. studied the nutrient digestibility and changes in feeding behavior of cattle fed cottonseed and vitamin E. During this study, six cannulated, non-pregnant, non-lactating Holstein cows were housed in bedded stalls and fed twice daily (Noguiera et al., 2019). The study was conducted over three twenty-one-day periods where each cow received each diet treatment. Treatments consisted of the control diet with no cottonseed, control diet with 30% cottonseed calculated into the ration, and control diet with 30% cottonseed and 500 IU vitamin E daily. High producing cattle require large amounts of energy. Many producers will supplement this need for extra energy by supplementing lipids (Noguiera et al., 2019). Feeding higher concentrations of lipids can have negative effects on digestibility within the rumen. The oil from cottonseeds is stored intracellularly and has a slower release of lipids (Noguiera et al., 2019). This can help lessen the negative effects of fat on digestion. Unsaturated fatty acids comprise 70% of the lipids in cottonseed. High levels of unsaturated fatty acids can have negative effects on dry matter (DM) intake and the intake and digestion of fiber (Noguiera et al., 2019). Thus, this study found that the inclusion of cottonseed increased energy within the diet by 30% (Noguiera et al., 2019). This increase in energy led to improvements in feeding behavior as cattle consuming cottonseed spent more time at the feed bunks and ruminating compared to the control diet without cottonseed. However, they did not find that vitamin E had any influence (Noguiera et al., 2019). Thus, the inclusion of cottonseed is recommended in feeding cattle on growing or finishing diets that require extra energy. This extra energy could allow for improved growth rates and promote higher average daily gains within growing cattle. Thus, the inclusion of cottonseed in cattle diets can help with feeding behaviors and increasing the time cattle spend eating in feedlot pens.

Tall-Fescue

Production Characteristics

Tall Fescue (*Festuca arundinacea Schreb*) is known to be one of the most important cool-season perennial grasses in the United States. This cool-season forage is native to Europe and made its way to North America in the late 1800s. Tall fescue is very popular for its longevity and versatile usage for livestock as a grazing pasture or hay (Ball et al., 1991). Tall fescue is commonly referred to simply as, “fescue” and is a persistent forage that is propagated through seed and tolerates overgrazing. Fescue is a cool-season perennial that has two major growing periods. These growing periods, in the eastern U.S. consist of September through December and begins again March through

June (Ball et al., 1991). Cool-season forages do not grow well during the warm summer months, thus slowing their growth pattern following cooler spring and fall temperatures. Less forage is produced in the cooler fall months. Fescue does remain green through the winter months and can grow in a wide variety soil pH's. Fescue is tolerant of close and overgrazing making this forage ideal for livestock pastures. Tall fescue is a bunch grass with an extensive root system. This forage grows well in drought and heat conditions compared to orchardgrass or Kentucky bluegrass and does grow best in full sun or partial shade (Ball et al., 1991). Tall fescue prefers fertile and well-drained soils but has the potential to grow in humid and water dense soils. Unfortunately, tall fescue does contain a toxic endophyte that can cause grazing issues within livestock species (Ball et al., 1991). Fescue is very versatile; uses include pasture, hay, green chop, or silage (Lacefield et al., 2003). Tall fescue would provide excellent quality forage for any livestock especially beef cattle.

Proper forage management is important to ensure high quality hay production. Properly managed tall fescue creates persistent and higher dry matter yields for the forage throughout the spring and fall months. Toxic-endophyte infected fescue can cause grazing issues within cattle. In the late 1970s, forage experts discovered the fungal endophyte (*Neotyphodium coenophialum)* that is commonly seen in infected tall fescue (Rogers and Locke, 2013). Tall fescue pastures that are infected are commonly referred to as being, "endophyte-infected," or "E^{+}." This fungus infects the fescue plant within the cells, meaning there is no outward identification for endophyte-infected pastures. Laboratory testing of the tall fescue plant tissue is required to determine the presence of the fungus (Rogers and Locke, 2013). The endophyte is only passed on through seeds of an E^+ fescue plant. The endophyte cannot be transmitted from plant to plant. This endophyte creates a mutual symbiotic relationship with the fescue plant and produces alkaloids that are beneficial for plant persistence (Rogers and Locke, 2013). The ergot alkaloids produced by the endophyte are considered toxic to grazing animals. This toxicity causes fescue toxicosis with symptoms that include reduced feed intake, decreased gain, lower milk production, increased respiration rate, elevated temperature, and reduced reproductive performance (Rogers and Locke, 2013). Fortunately, there are endophyte-free tall fescue varieties that have been created for safe livestock grazing. However, when the endophyte is taken away from the forage, plant persistence suffers, and the tall fescue pasture is less resistant to drought and insect tolerance. Novel-endophyte infected tall fescue has been created for safe livestock grazing, as it does not contain the toxic ergot alkaloids that cause fescue toxicosis (Rogers and Locke, 2013). This endophyte infected fescue is manually inoculated to create safe alkaloids that create a symbiotic relationship with the forage but still allow safe grazing.

Tall fescue should be established in the fall instead of spring planting because during the spring months, the forage will have little time to establish and grow before intense summer heat and drought. Fescue is easy to establish with good quality seed. High quality stands can be developed utilizing no-till or conventional tillage practices (Rogers and Locke, 2013). Tall fescue should not be grazed or hayed during the first spring following establishment. This will allow for the root system to develop for good stand persistence. Fortunately, tall fescue is ready for utilization the fall following establishment. Tall fescue responds well to nitrogen fertilizer. Nitrogen fertilizer should be applied up at 50 kgs per acre in a year (Rogers and Locke, 2013). This should be completed over multiple applications. Tall fescue can be established with legumes, especially clover varieties. Quality of tall fescue is the highest during the fall and spring and should be cut for hay during those periods. Quality and DM yield diminish during the summer and warm months. Tall fescue has a typical crude protein contain of 16%, which is higher than other popular cool season perennials orchardgrass and timothy (Rogers and Locke, 2013; Table 2). This makes tall fescue an excellent forage option for hay utilization within finishing rations in beef cattle.

Nutrient Content

Table 2. Nutrient Content of Tall-Fescue Hay (NRC, 2016)

Component	Amount
DM (%AF)	88.93 ± 3.58 (96)
Ash (% DM)	8.35 ± 0.70 (4)
TDN (% DM)	58.3 ± 2.52 (5)
ME (Mcal/kg)	2.11
Fat (% DM)	2.10 ± 0.80 (6)
NDF (% DM)	9.22 ± 3.02 (95)
ADF (% DM)	3.10 ± 0.57 (5)
CP (% DM)	8.65 ± 4.01 (19)
Ca (% DM)	0.48 ± 0.18 (45)
P (% DM)	0.22 ± 0.08 (45)
K (% DM)	0.17 ± 0.06 (19)

Animal Performance

Tall fescue is commonly used for pasture, hay, silage, and green chop and utilized by many classes of livestock. During the vegetative or leafy stage, tall fescue reaches its highest quality (Rogers and Locke, 2013). As fescue matures, the quality declines for livestock consumption. Animal performance on endophyte-free fescue is superior to those cattle grazing endophyte infected-fescue. In a three-year study at the Noble Foundation, spring average daily gain was 1 kg while grazing novel endophyte infected fescue (Islam et al., 2011). Indicating that average daily gains on fescue containing the endophyte can still result in high average daily gain. Tall fescue also has a high protein content (15-16% DM) making this forage excellent for underweight or finishing cattle (Rogers and Locke, 2013). High protein content makes tall fescue a more desirable hay and pasture forage for growing and breeding cattle. Fescue is readily available in the southeastern region indicting preferences of farmers to select for pasture usage and hay. Tall fescue has high protein content and is highly digestible and palatable for many different livestock species. This combination of exceptional traits makes fescue an affordable and easy option for many livestock producers, especially in the southeastern U.S.

Corn

Whole or processed corn is commonly fed in the United States to beef cattle as part of their daily ration. Corn contains approximately 72% starch on a DM basis and is lower in protein compared to other feed grains (Lardy, 2018). Corn is a high-energy feed ingredient that is often utilized in feedlot and stocker rations. The protein content in corn has 65% escape or bypass protein (Lardy, 2018). Escape protein is not fermented or degraded by the ruminal microorganisms but is digested and absorbed by the animal in the small intestine (Lardy, 2018). The other 35% of protein in corn is rumen-degradable protein. Rumen microbes require this degradable protein source for growth and protein synthesis (Lardy, 2018). Corn is high in phosphorus and low in calcium, meaning diets fed large amounts of corn should be supplemented with calcium (Lardy, 2018; Table 3). The recommended calcium to phosphorous ratio is 2:1 in cattle diets. To supplement a finishing diet, to ensure a 2:1 calcium phosphorus ratio, feedlot producers can provide limestone in their daily ration. Limestone can help prevent urinary calculi or kidney stones that are solid particles in the urinary system that are difficult and painful to pass (Lardy, 2018). Proper formulations and daily rations of corn can be fed easily to cows to provide more energy to their diet and promote digestion.

Nutrient Content

Table 3. Nutrient Content of Corn Grain, Dry Rolled (NRC, 2016)

Component	Amount
DM (%AF)	87.22 ± 3.25 (31.123)
Ash (% DM)	1.44 ± 0.29 (7.166)
TDN (% DM)	87.6 ± 1.83 (6.452)
ME (Mcal/kg)	3.17
Fat (% DM)	3.81 ± 0.52 (15,057)
NDF (% DM)	9.72 ± 1.83 (6,999)
ADF (% DM)	3.56 ± 0.88 (7,582)
CP (% DM)	8.79 ± 0.97 (22,868)
Ca (% DM)	0.03 ± 0.06 (6,655)
P (% DM)	0.29 ± 0.05 (10,980)
K (% DM)	0.37 ± 0.05 (8,362)

Animal Performance

Corn can be fed in a cow's diet in a variety of forms such as dry rolled corn, high-moisture corn, steam-flaked corn, ear corn, earlage, snaplage and many others (Lardy, 2018). Processing corn can increase digestibility by 5-10% in cattle (Lardy, 2018). Grinding or rolling corn will not improve average daily gain and should be avoided in commercial beef diets. Finely ground corn should be avoided in cattle diets as fine-ground corn can ferment quickly within the rumen. This quick fermentative action can result in serious and even deadly disturbances including acidosis or founder. Most commonly, corn is fed whole or cracked to cattle within their daily feedlot ration. Processing corn through steam rolling or flaking can increase starch digestion within ruminants (Lardy, 2018). When corn is fed whole in a cow's diet, cattle must process the corn themselves via mastication or chewing which allows them to break down the kernel and utilize the starch content (Lardy, 2018). From a formulation standpoint, rolled or crack corn can be mixed more completely compared with whole corn (Lardy, 2018). Corn can be used in a variety of diets for cattle, such as backgrounding and finishing diets. Corn is low in protein and high in starch (Lardy, 2018). For that reason, high quality forages are preferred since the low protein and high starch content within corn can negatively impact forage utilization (Lardy, 2018). When producers use corn as a forage supplement, they need to ensure there is adequate rumen-degradable protein available for the rumen microbes (Lardy, 2018). This is important to prevent any depression in forage digestibility. In finishing or backgrounding diets, corn can be the sole grain source (Lardy, 2018). Corn intake should be tailored to the desired cattle performance. Additional energy can be added to the diet through corn for growing and finishing cattle (Lardy, 2018). Corn has a low crude protein content, producers feeding primarily corn in growing and finishing diets need to supplement additional protein to the diet. Generally, rations fed to cows should contain no more than 0.25% BW of corn daily. Amounts over this for a daily ration are considered extreme. Thus, feeding a cow at 0.25% body weight daily is a great energy supplement during any state of production.

Corn By-products

Cattle diets that utilize large amounts of by-products during finishing can lead to wasted crude protein and metabolizable energy. Many beef producers feed cattle corn by-products as a relatively inexpensive way to add energy to a growing or finishing ration. Distillers' grains have a higher protein content than corn (Jennings et al., 2018). Formulated diets with higher amounts of distiller's grain can lead to diets containing greater concentrations of crude protein and metabolizable protein than required. Thus, excess protein or nitrogen is converted to urea in the liver and then excreted via the urine (Jennings et al., 2018). A study conducted by Hales et al., (2016) evaluated the effects of dietary protein concentration on finishing beef steers fed a diet containing 0% or 45% wet distiller's grain plus solubles. They found that nitrogen excretion in the urine increased with the higher amounts of distiller's grain solubles within the finishing diet. They also found that the crude protein concentration was not affected by nitrogen retention rates within the steers. As the amount of distiller's grain solubles increased within the finishing diet within cattle, metabolizable energy intake decreased (Hales et al., 2016). Thus, showing that as the amount of protein in the diet increases energy efficiency and utilization decreases. Showing that increasing protein within a cow's diet is not efficient in producing more energy in the diet and can have a negative impact on animal growth. Therefore, feeding distiller's grain within a cow's diet can be an excellent way to add protein to the ration but producers need to understand excess protein within a diet will not be used.

Corn By-product Industry

In the United States there has been a large growth in the ethanol industry which creates a high-protein byproduct that is commonly used in animal feed rations. This by-product is distiller's grains plus soluble (DGS). Distillers' grains have a high protein content and they are resistant to ruminal degradation, making them an excellent source of RUP or rumen undegradable protein (Kleinschmit et al., 2007). Previous research has indicated that the rumen undegradable protein of distiller's grains is around 50% (Kleinschmit et al., 2007). Distillers grains are a cereal by-product of the ethanol industry. This by-product consists of a mix of corn, rice and other grains that are left over after the distillation process (Kleinschmit et al., 2007). The price of distillers' grains is directly related to the cost of corn. The USDA estimates that the amount of corn being used to produce ethanol and corn by-products has been increasing over the past decade (Irwin and Good, 2013). The USDA stated that the bushels of corn utilized in ethanol production increased by the billions of metric tons (Irwin and Good, 2013). They expect this increase to continue in the decades to come, showing the popularity of ethanol production. With the boom in ethanol production over the previous two decades, the popularity of ethanol by-products has increased as a result. The production of distiller's grains has increased directly because of the increase in ethanol production. This increase has allowed animal nutritionists to take advantage of this high-protein by-product and utilize DGS in animal feed rations.

Distillers grains solubles are marketed and sold as dry, modified wet and wet distillers' grains solubles. The most popular form that is sold and utilized on the animal feed market is dried distillers' grains solubles or DDGS (Irwin and Good, 2013). The utilization of grains in domestic livestock feeding is over 163 billion kgs each year (Irwin and Good, 2013). Distillers' grains solubles accounts for a large portion of this amount because of their popularity within animal feed rations. With the increase in the utilization of distillers' grains solubles in animal rations, there has been a decline in the feeding of whole corn since 2008 and the drop in the U.S. economy (Irwin and Good, 2013). The rise in popularity of distillers' grains solubles can be accounted for by their high metabolizable energy and protein content which is very appealing in animal nutrition. The carbohydrate content in distillers' grains has a higher percentage of fiber than corn, which has a higher starch content (DiCostanzo, 2018; Table 4). Dry matter content varies between production plants, but ultimately produces a DM content between 25 to 35% or 45 to 50% depending on the producer (DiCostanzo, 2018). Distillers' grains are commonly used as a both high-energy and high-protein feed for growing and finishing cows in beef production. Distillers' grains unfortunately do have a variable nutrient content due to moisture and storage of the DGS (DiCostanzo, 2018). These changes can lead to differences in the protein and dry matter content of the distillers' grains. DGS can have a high sulfur and phosphorus content. Growing or finishing cattle need 0.15 percent sulfur each day with a maximum of 0.40 percent (DiCostanzo, 2018). Understanding where the sulfur is coming from in a cows' diet is important in preventing over consumption of sulfur. Thus, beef producers need to get samples of distillers' grains prior to purchasing to adjust and plan the cows daily ration based upon sulfur and phosphorus content (DiCostanzo, 2018). With the high sulfur and phosphorus content in distillers' grains, producers can utilize this to ensure that growing and finishing cattle are receiving adequate daily intake. Distillers' grains solubles are an excellent source of energy and protein for growing and finishing beef cattle and are an easy cereal grain by-product that can be added to a daily feed ration for utilization by the cattle.

Nutrient Content

Table 4. Nutrient Content of Distillers Solubles, Corn (NRC, 2016)

Component	Amount
DM (%AF)	30.89 ± 6.02 (584)
Ash (% DM)	9.11 ± 1.72 (2,126)
TDN (% DM)	98.0 ± 7.79 (112)
ME (Mcal/kg)	3.54
Fat (% DM)	16.85 ± 5.00 (9,764)
NDF (% DM)	4.71 ± 2.74 (99)
ADF (% DM)	3.81 ± 2.14 (325)
CP (% DM)	18.94 ± 4.92 (9,719)
Ca (% DM)	0.11 ± 0.07 (4,477)
P (% DM)	1.52 ± 0.35 (4,759)
K (% DM)	2.34 ± 0.58 (4,194)

Distillers' grains solubles should be provided in the feedlot ration at 15-25% of the ration daily. Distillers' grains have a high protein content, feeding any amount over the recommended daily intake of DDGS will be excreted through the urine and not utilized by the animal (DiCostanzo, 2018). Since they are a good source of energy, DDGS are commonly fed to growing and finishing cattle. Along with replacement heifers or calves that need additional supplementation (DiCostanzo, 2018). Distillers' grains are composed of the fiber, protein, and mineral fractions of the corn kernel. During the distillation process, the starch content is fermented first and what remains is the by-product, distillers' grains, produced from the corn (Stewart et al., 2017). The protein content of DDGS are split 50 to 50 with half being degradable protein and the other half being undegradable protein. If degradable protein is deficient, forage digestion will decrease and alone is not enough protein supplementation for the small intestine (Stewart et al., 2017). Undegradable protein is also needed in the ruminant diet to improve growth and weight gain in young cattle. Distillers' grains are known to be an excellent source of energy because of it contains 85-95% total digestible nutrients (Stewart et al., 2017). Energy derived from distillers' grains is primarily from digestible fat and fiber since the starch content is removed during the distillation process (Stewart et al., 2017). The fat content of DDGS is 10 to 14% which is due to the presence of solubles. Calcium content is low in DDGS and should be supplemented within the diet to ensure the proper 2:1 calcium to phosphorus ratio (Stewart et al., 2017). Lastly, when developing a ration containing distillers' grains, the form is the most important part of selection and formulations. Most producers feed dried distillers' grains solubles (Stewart et al., 2017). With the increase in ethanol industry, the production of cereal grain by-products will continue to grow. Distillers' grains are an excellent source of energy and protein for growing cattle and are an inexpensive valuable feed source for livestock.

Weaning

In the beef production system, producers are classified as seedstock, cow-calf, stocker, or feedlot and contribute to the meat production chain. Rarely do producers market and sell in all four sectors of the beef production chain. All sectors work together to produce beef cattle for meat production. Cow-calf producers focus solely on breeding and reproducing offspring that enter the beef production chain. Calves are born and stay with their dam until they reach 6-months in age when they are weaned. Weaning is the act of removing an animal from their dam's milk and adjusting them to dry feed (Enríquez et al., 2011). Within the beef industry, calves are usually weaned abruptly compared to the gradual weaning that can be seen within other animal species (Enríquez et al., 2011). This abrupt weaning causes increased stress for the animals, as this is their first time being separated from their dams. This quick and abrupt separation can cause behavioral and psychological problems within these newly weaned calves (Enríquez et al., 2011). Understanding and creating solutions for this stressor within the calves can help to ease them into separation from their dam without extreme harm. The main objective for weaning in a cow-calf production system is to allow the dam to begin to improve body condition, which in return will help to prepare her body for her next lactation when the new calf is born (Enríquez et al., 2011). Another objective is to wean the calf off milk entirely and to start the consumption and weight gain on dry feed (Enríquez et al., 2011). These two objectives work together to create a productive cow-calf production system and are needed to keep the breeding programs on track. However, there have been studies showing the importance of minimizing stress on weaning calves to help with their health, weight gain, and performance (Enríquez et al., 2011). The stress of weaning has been shown to greatly impact finishing weights during the stocker or feedlot phase of production before they are slaughtered (Enríquez et al., 2011). Reducing and managing the stress of weaning is crucial in the weight gain and performance of beef calves. Helping to reduce these stressors can help to improve average daily gains and maintain good health amongst the weaned herd.

Abrupt-Separation Weaning

Primarily beef calves are weaned abruptly and separated from their dams at 6-months of age to allow time for the dam to recover and prepare for her next calf. The time needed to recover for lactating dams is crucial in rebreeding programs. Dams need time to reach a body condition score of 5 or 6 before conceiving again (Riggs et al., 2011). Thus, total separation is utilized within the beef production industry. Calves are taken from their dams around 6-months of age and separated into groups to be weaned. Total separation is needed so that the calves become independent and are grown to be sold. Abrupt separation between dam and calf occurs when calves are rounded up and taken from their dams directly (Riggs et al., 2011). They are not comingled with their dams again and are grouped and feed in a different location on the farm or facility (Riggs et al., 2011). This can be done in two ways: calves are removed and placed in a drylot or a pasture. There are many upsides to directly removing the calf from the dam. Such as, if the calf is abruptly removed from the dam, the producer can sell the calf right off the cow (Riggs et al., 2011). This practice also allows more forage to be available for the recovering dams left in the pasture after the calves are removed (Riggs et al., 2011). This decreases the need to reserve or purchase additional forage for the dams while they are recovering and about to give birth again. Forage management is a large part of beef production and can get very expensive. By abruptly weaning calves, producers can alleviate the need for extra forage as the calves are removed from the pasture (Riggs et al., 2011). Abruptly separating calves can induce extreme stress on the calves which can ultimately negatively impact performance. Calves are moved and expected to adapt to a new diet and environment. Without any exposure to this new environment or diet, calves can become stressed easily and lose weight quickly. Reducing and mitigating this stress is crucial in helping producers increase average daily gains post weaning. This stress can retard performance of freshly weaned calves, thus finding a solution or alternative weaning practices can help control and reduce stresses associated with weaning.

Creep-Feeding

Reducing and mitigating weaning stress in beef calves can help to improve performance amongst these growing calves. Some of the methods used in reducing stress can help the calf cope with the new diet and separation from their dam (Enríquez et al., 2011). Other methods focus on trying to mimic the natural weaning process. These methods include milk production by the dam before final separation or weaning occurs (Enríquez et al., 2011). Diet changes tend to be a large stressor within the weaning process. Providing high quality feed or pasture can help the calves' transition to the new diet (Enríquez et al., 2011). This can be done through creep feeding. Creep feeding should be avoided in replacement heifers (Enríquez et al., 2011). Creep feeding allows the young calves to consume higher quality forages or dry feed that can help transition their diet and allows producers to supplement the young calves' diets while preventing their dams from consuming the ration (Enríquez et al., 2011). This practice is done by utilizing a creep feeder within a pasture where only calves can access the forage or feed. Creep feeding is done while the animals are still growing and suckling to get them acclimated to forage and feed before weaning (Enríquez et al., 2011). This practice can help reduce stress when completely switching their diet over from milk to forage. Previous studies have shown that beef calves conditioned to hay prior to weaning ate for longer periods of time (Enríquez et al., 2011). These calves showed less behavioral distress during weaning compared to the calves who were not conditioned to hay (Enríquez et al., 2011). Creep feeding or grazing can help reduce the stress of changing diets abruptly through weaning. Thus, minimizing the stress of diet changes during weaning since calves are already preconditioned to consuming forages and other animal feed types.

Fence-Line Weaning

Separation from the dam is the main issue associated with weaning beef calves. The bond between dam and calf is a physiological bond that is formed between the two animals and is very hard to overcome (Enríquez et al., 2011). In the natural setting, the survival of the newborn or young calves depends greatly on the relationship between the dam and the calf (Enríquez et al., 2011). During weaning, the calf no longer has their dam to depend on for protection. This creates stress within the beef calves. One way of reducing this is by weaning through a fence line (Enríquez et al., 2011). Fence line weaning allows the young calves to be separated from their dams, but they are still able to see and hear them (Enríquez et al., 2011). This method slowly breaks the bond between calf and dam through a fence. Producers separate calves and dams through a strong fence that allows for comfort and assurance during the beginning of the weaning process (Enríquez et al., 2011). The fence must be strong and well built, as the stress of weaning can cause many young calves to injure themselves by trying to reach their dams through the fence (Enríquez et al., 2011). They can see them, but they cannot nurse or touch them. Some studies indicate that by separating calves through a fence prior to fully weaning them can begin the process of weaning more naturally (Enríquez et al., 2011). During one study, calves and dams were separated with a fence for a few days prior to weaning and final separation. This study found that the calves had higher average daily gains, calves spent less time walking, and vocalized less (Enríquez et al., 2011). Calves during this study spent more time by the fence indicating they were wanting to be reunited with their dams (Enríquez et al., 2011). Thus, fence line weaning is a great way to transition beef calves from being with their dams to final separation. This practice can help reduce stress from weaning and allow the calves some ease by seeing their dams across the fence. Thus, reducing stress and promoting higher average daily gains once they are finally weaned.

Two-Stage Weaning

Another method of alleviating stress amongst freshly weaned calves is to conduct two-step or two-stage weaning. During this method of weaning, a device is implanted to prevent the calf from suckling the cow (Riggs et al., 2011). These devices are rings that can be attached to the nose of the calf to prevent them from nursing (Riggs et al., 2011). The first step of this weaning practice involves the usage of the nose ring to prevent the calf from receiving milk. This happens while the calf is still turned out with the dam's cows (Riggs et al., 2011). This first step is crucial, as the device implanted within the nose of the calf does not allow them to drink their dams milk. This step can help the calf to become acquainted with other feedstuffs. These feed stuffs include hay or supplemental grain to allow the calves to begin consuming this as their primary diet (Riggs et al., 2011). The second step of this weaning practice involves the total separation between calf and dam (Riggs et al., 2011). Since the calves are already accustomed to not drinking their dams' milk, they are more comfortable during the final separation consuming only the ration of high-quality forage and grain. During a study in 2005, calves assigned to the two-stage weaning practice spent less time vocalizing and walking (Haley et al., 2005). These calves also spent more time eating and grazing compared to the calves weaned abruptly. This study also reported higher average daily gains for calves weaned through two-stage weaning (Haley et al., 2005). Making sure the calves are receiving adequate nutrients while they are not lactating is a priority to ensure there is no pre-weaning weight loss. High quality forages should be provided to these calves before and after final separation to allow for improved performance amongst these two-stage weaned calves. Thus, this form of weaning can help to reduce stress and improve performance amongst weaned calves.

Post-Weaning Weight Gain

Weaning is a stressful and necessary stage in beef production that should be done as stress free as possible to allow for calves to grow during post-weaning. Management during the post-weaning period of beef calves is crucial in the performance and growth rate of the animals. Nutrition and formulation of post-weaning diets help to create a less stressful time for both producers and calves (Riggs et al., 2011). If weaning is very stressful and the calves begin losing weight, diets must include high-energy feed and protein to halt loss in weight (Riggs et al., 2011). This stress can prevent the calves from eating or drinking. Readily available water and high-quality forage are required during weaning and the stocker phase of production (Riggs et al., 2011). Stress can cause the calves to refuse forage or feedstuffs, providing high-quality and highly palatable feeds are needed in the post-weaning diet (Riggs et al., 2011). Typical post-weaning diets include a high-quality forage, high-starch feedstuff such as corn or barley, and a non-forage fiber source like soybean hulls, or distillers' grains (Riggs et al., 2011). High quality diets will consist of proper daily rations of forages, corn or barley, and distillers' grains (Riggs et al., 2011). The combination of these feed ingredients can help improve performance and increase intake within post-weaned calves (Riggs et al., 2011). Weaning is a stressful time for calves, thus post-weaning diets need to provide extra energy and protein to help limit any weight loss that can occur within the first few weeks post-weaning. High quality diets can help promote healthy calves and increased weight gain during the post-weaning phase. This weight gain and growth can help each calf sell for higher prices on the market which in turn will result in larger profits for the producers.

After beef calves are weaned, they move into the next phase of beef production called the stocker phase. Meaning, producers are raising calves between the weaning and feedlot period. During the stocker phase, weaned calves are either placed on a drylot or in a pasture to put on weight and grow (Bock et al., 1991). The goal of the stocker phase of production is to purchase or raise calves inexpensively and sell them for a high price. This phase of production usually lasts around 6-months and once complete, cattle are sold at market around 12 months of age to enter into the next production phase which is feedlot or the final stage of beef production (Bock et al., 1991). Calves are raised primarily on high-quality forage diets for 6-months before being sold to the feedlot. The stocker phase can be completed on a grazing-pasture or feedlot based drylot (Bock et al., 1991). Calves in the stocker system are typically going to be sold for beef in the future, with the goal of adding weight quickly and at a low cost. This phase of production has a goal of cheaply putting weight on weaned calves and selling them for a high profit (Bock et al., 1991). These calves are not grown to complete market size or weight. This phase of beef production is known as the middle phase of production, allowing calves to adjust to weaned life and growing on high quality forages.

Drylot Stocker Production

During the stocker phase of beef production, calves are freshly weaned and moved to a drylot or grazing pasture for weight gain and growth. Drylots are used as an alternative solution to grazing pastures. These paddocks are usually dirt or gravel based with a water source available for utilization by the cattle. The utilization of a drylot can help decrease expenses in a beef production operation (Bock et al., 1991). Forage management is a large part of beef production. Forage can get expensive if pasture grazing is not monitored and managed correctly (Bock et al., 1991). Drylots can be used to prevent overgrazing on pastures so that remaining grasses can be utilized by pregnant cows remaining on the farm. Weaning calves onto a drylot allows for further utilization of pastures by their dams to recover from lactation and begin to prepare for their next calf (Bock et al., 1991). Once in the drylot, weaned calves can begin to adjust to a feedlot ration. This ration usually consists of hay, corn or barley, and a corn by-product such as distillers' grain (Bock et al., 1991). Once on a drylot, producers can ration out and provide exact amounts of feed for the weaned calves to receive. Drylots are an economical solution to overgrazing of pastures and can help beef producers add weight to calves without jeopardizing additional grazing pastures (Bock et al., 1991). Drylots can increase stress on weaned calves since they are not accustomed to smaller confined areas without constant grass available to graze. This stress could reduce average daily gains during the stocker phase of production which can result in decreases in profit for the producer. Although drylots can be a solution for forage management they can also create stress and should be monitored during stocker production for beef claves to ensure the calves are healthy and gaining weight.

Pasture Stocker Production

Freshly weaned calves are generally highly stressed and can contract diseases during their post-weaned phase. If calves are weaned in a drylot, this can help forage management by allowing more grazing land to be available for other cattle to consume while stocker calves are growing. Drylots can create respiratory issues in weaned calves and conditions of the drylot must be managed and kept clean to prevent further disease (Paisley et al., 2000). To prevent respiratory illness from a drylot, producers can turn the weaned calves onto grazing pasture instead. If the producer has the land and can utilize the grazing land for weaned calves, this can help reduce stress and allow for natural grazing by the weaned calves (Bock et al., 1991). Pasture programs can reduce stress since cattle are able to remain on a forage diet and can spread out to naturally graze. These calves also have less risk of disease since the calves are not kept near each other and have the chance to spread out (Bock et al., 1991). During one study, Angus calves were conditioned into a grazing pasture in Kansas. During this study, calves gained on average 0.73 kgs per day. Thus, showing that pasture conditioning programs are an efficient way to put weight on a weaned calf. Ultimately grazing on a pasture can reduce stress and allow the weaned claves to spread out on an operation but drylots allow for better forage management and utilization for other cattle on the property.

In conclusion, the stocker phase of production is important for post-weaned calves as this conditioning program allows for freshly weaned calves to grow and put on weight under controlled conditions. This phase of production generally lasts 6-months and be an easy way for producers to produce a profit. Calves are generally purchased or raised as inexpensively as possible and then fed for 6-months and sold based upon weight to the market. This phase of production may be very profitable for producers and may utilize a drylot for improved forage management or grazed pasture to help limit stress of weaned calves. Both have been shown to increase growth rates and promote weight gain amongst post-weaned calves during their 6-monnths in the stocker phase of production. Additional supplementation through feedlot rations can also increase energy and weight gain for these stressed calves during this transitional time in their early life.

MATERIALS AND METHODS

Research Site

This study was conducted at the Western Kentucky University specifically – the AREC located, in Bowling Green, KY and utilized calves from three weaning periods (fall 2019, 2020, and spring 2020). Each feeding period lasted for 50 days. Calves were stratified by body weight and sex and randomly assigned to treatments. After, allotted calves were placed in one of four feedlot pens (n=2/treatment). The feedlot facility was equipped with five-fenced drylot paddocks and a partial covering over the paddocks to protect the calves from the elements.

Cattle

During all three periods of the study, cattle were freshly weaned from their dams and moved to the feedlot area. These calves were primarily Black Angus or Angus/Hereford crosses. Each trial consisted of heifers, steers, and bulls. In trials 1 and 3, calves were born in the spring and weaned in the fall. In trial 2, calves were born in the fall and weaned in the spring. Trial 1 had (n=18) weaned calves, trial 2 had (n=18) weaned calves, and trial 3 had (n=16) weaned calves. Calves were vaccinated and dewormed prior to entering the stocker phase of production. Calves were weaned at 4-6 months of age and weighed on average over 180 kgs prior to entering the feedlots.

Experimental Design and Treatments

Calves were randomly assigned using Microsoft Excel into four different groups with two treatments. Treatment one was the control and treatment two was the control plus cottonseed supplementation. Groups one and three were designated the control treatment groups and groups two and four were designated the cottonseed supplementation treatment groups. Calves were placed into groups one, two, three, and four in the feedlots in a chronological order to ensure accurate feeding every other day. Feedlot pens were numbered one through four and the corresponding groups of calves were placed in the matching feedlot pen. Each group of calves had an even distribution of heifers, steers, and bulls to keep average weights within the treatment groups similar.

The base diet consisted of a feedlot ration of 23% corn, 25% tall-fescue hay, and 52% distillers soluble. Calves began the study being fed 2.5% BW per day, as the trials progressed this number increased from 2.5% to 3.0-3.5% BW daily to meet the weaned calf's energy requirements. This diet was calculated for each group of calves and distributed every two days for consumption. In the feed mixer, corn, orchardgrass hay, and distillers solubles were weighed and mixed prior to feeding. Once mixing was complete, rations were weighed and fed to groups one through four in their feedlot bunks.

The control treatment groups received the base feedlot ration every two days and the cottonseed treatment groups received the base feedlot ration every two days with additional cottonseed supplementation. Treatment groups two and four were fed an additional 1.0% BW daily in whole cottonseeds. The whole cottonseeds were top dressed on top of the base feedlot ration after the ration was dumped into the feed bunks. Hand mixing was used to help incorporate the whole cottonseeds into the base ration for improved acceptance of the cottonseed additive. Both treatment groups were monitored daily to see how quickly both diets were being consumed to determine if an increase in their daily ration was necessary.

Additional whole cottonseed diets were consuming additional energy and protein compared to the control diet. Thus, the level of consumption and palatability of the whole cottonseed could have been impacted based upon the 1% additional supplementation with the base ration already providing a complete nutrient ration for the weaned calves.

NUTRIENT CONTENT OF FEED RATION

Whole Cottonseed

Table 5. Nutrient Content of Whole Cottonseed (NRC, 2016)

Component	Amount
DM (%AF)	92.63 ± 2.10 (529)
Ash (% DM)	7.53 ± 1.76 (549)
TDN (% DM)	93.0
ME (Mcal/kg)	3.36
Fat (% DM)	19.45 ± 2.59 (534)
NDF (% DM)	47.82 ± 6.96 (192)
ADF (% DM)	42.85 ± 5.80 (90)
CP (% DM)	22.87 ± 2.53 (536)
Ca (% DM)	0.22 ± 18.48 (165)
P (% DM)	0.53 ± 0.09 (94)
K (% DM)	1.12 ± 0.14 (57)

Tall-Fescue Hay

Table 6. Nutrient Content of Tall-Fescue Hay (Cumberland Valley Analytical Services, 2020)

Component	Amount
TDN (%DM)	58.4
ME (Mcal/lb)	0.97
CP (%DM)	8.3
Ammonia (%DM)	2.7
ADF (%DM)	39.4
Starch (%DM)	2.3
Fat (%DM)	2.43
Ca (%DM)	0.36
P (%DM)	0.20
K (%DM)	1.77

Cracked Corn

Table 7. Nutrient Content of Cracked Corn (Burkmann Nutrition Feed Store)

Component	Amount
Crude Protein (%AF)	6.25
Crude Fat (%AF)	2.50
Crude Fiber (%AF)	3.50

Distillers' Solubles

Table 8. Nutrient Content of Distillers Solubles, Corn (NRC, 2016)

Component	Amount
DM (%AF)	30.89 ± 6.02 (584)
Ash (% DM)	9.11 ± 1.72 (2,126)
TDN (% DM)	98.0 ± 7.79 (112)
ME (Mcal/kg)	3.54
Fat (% DM)	16.85 ± 5.00 (9,764)
NDF (% DM)	4.71 ± 2.74 (99)
ADF (% DM)	3.81 ± 2.14 (325)
CP (% DM)	18.94 ± 4.92 (9,719)
Ca (% DM)	0.11 ± 0.07 (4,477)
P (% DM)	1.52 ± 0.35 (4,759)
K (% DM)	2.34 ± 0.58 (4,194)

Data Collection and Analysis

Each trial lasted 50 days, calves were weighted at weaning (d=0) for treatment allotment, the start of the trial (d=1), halfway through (d=25), and the final day (d=50). These weights were used to calculate average daily gains from using weights from start to middle, middle to end, and start to end to analyze any weight gain during each phase of the trial between the two treatment groups.

S2W = Weaning weight minus starting weight Eq. 1

S2M = Starting weight minus the middle weight Eq. 2

M2E = Middle weight minus the end weight Eq. 3

S2E = Starting weight minus the end weight Eq. 4

ADG = S2E divided by 50 Eq. 5

ADGs = S2M divided by 25 Eq. 6

ADGm = M2E divided by 25 Eq. 7

Average daily gain (ADG) was calculated at the end of each trial for both groups to analyze additional weight gain from the supplementation of cottonseed with the base ration. The first 25-day and second 25-day average daily gain (ADGs and ADGm) were calculated to analyze the weight gain during the first and last 25 days of the trial.

Statistical Analysis

Data was analyzed using the PROC MIXED procedure of SAS 9.4 (SAS Inst. Inc., Cary, NC). Dependent variables evaluated included S2W, S2M, M2E, S2E, ADG, ADGs, and ADGm. The main effects included the treatment and trial. The PDIFF option of LSMEANS was used to separate means when protected by F-text at $\alpha = 0.05$. Trends were declared at $0.10 \leq \alpha \leq 0.05$.

RESULTS

First 25-Days:

Average daily gain was affected by treatment *(P* = 0.02*)* with included cottonseed having greater ADG compared with basal diet. During the first 25-days of all three trials, the average daily gain was 0.5 kg/day across treatments. Whole cottonseed diets gained on average 0.68 kg/day compared with the control diets which gained 0.34 kg/day (Table 9, Figure 1). During the first 25-days, weaned calves were adjusting to the finishing ration and receiving large amounts of corn and dry forage for the first time. Whole cottonseed diets increased average daily gain during the first 25-days of the three trials. Base rations were composed of 23% corn, 25% tall-fescue hay, and 52% distillers' solubles. Whole cottonseed was supplemented with the base ration at an additional 1% BW in half of the weaned calves' diet. Whole cottonseed is a high energy and protein content feed ingredient. With the inclusion of whole cottonseed in a freshly weaned calf diet, average daily gain has the potential to increase with the additional feed supplementation in the diet.

Average daily gain was affected by trial (*P* < 0.0001) where trial 1 ADG was greater than trials 2 and 3, which did not differ (Table 10, Figure 1). Trial 1 was the first trial conducted with 18 weaned calves in the fall of 2019. Trials 2 (n=18) and 3 (n=16) occurred in the spring and fall of 2020, respectively, resulting in similar average daily gains during the first 25-days of the two trials. Meaning, the calves from trial 1 performed the best during the first 25-days of this research.

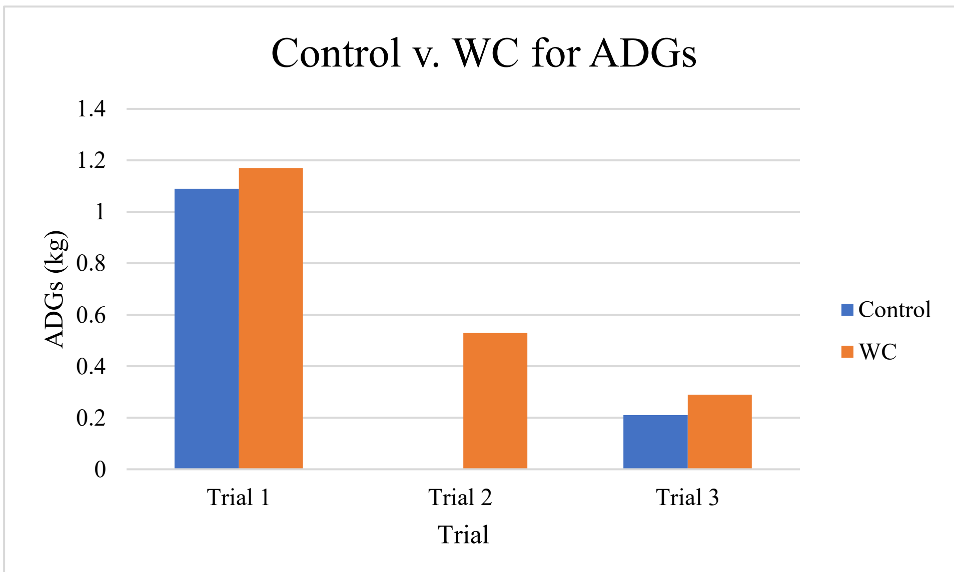

Figure 1: Control v. Whole Cottonseed on ADGs During First 25-days

Final 25-Days:

Average daily gain *(P* = 0.4*)* was not affected by treatment across the three trials during the final 25-days. During the last 25-days of all three trials, the average per kilogram weight gain each day was 1.03 kg/day amongst all treatments. Whole cottonseed diets gained on average 1 kg/day which is slightly lower than the average weight gained for the control diets which was 1.07 kg/day (Table 9, Figure 2). Calves consuming the base ration gained slightly more weight during the final 25-days of all three trials. Calves began the study being fed at 2.5% BW each day, as the trial continued, weaned calves consumed the ration quicker as the trial continued. For this reason, the ration was steadily increased to 3.0-3.5% BW to increase the amount consumed by the weaned calves. This increase saw a higher average daily gain between all the weaned calves in the final 25-days compared to the first. Both diets saw an increase in average daily gains during the final 25-days of the three trials, indicating that as the amount of feed increased within the diet, a positive relationship formed with the average daily gains. This positive relationship showed that as the % BW fed daily increased, animal performance followed a positive relationship and increased in return. This indicates that by increasing the % BW the weaned calves are fed slowly over the course of a 50-day trial, calves will increase in growth and weight gain.

Average daily gain was affected by trial *($P < 0.0001$)* with trial 2 being different then trials 1 and 3, which were not different (Table 10, Figure 2). Trials 1 and 3 were both conducted in the fall when temperatures are significantly warmer compared to the spring. Thus, weaned calves performed similarly during those warmer periods during trials 1 and 3 when evaluating ADGm. Trial 2 was conducted in the spring during cooler temperatures showing a significant difference in ADGm between when comparing the results to trials 1 and 3. Calves performed better during the cooler spring months compared to the warm fall trials, thus, showing the significant differences in trial 2 compared with the fall trials 1 and 3. Average daily gains during the final 25-days increased within weaned calves during the cooler spring months, showing the potential of increasing average daily gains during the cooler months of the year could help promote growth and weight gain.

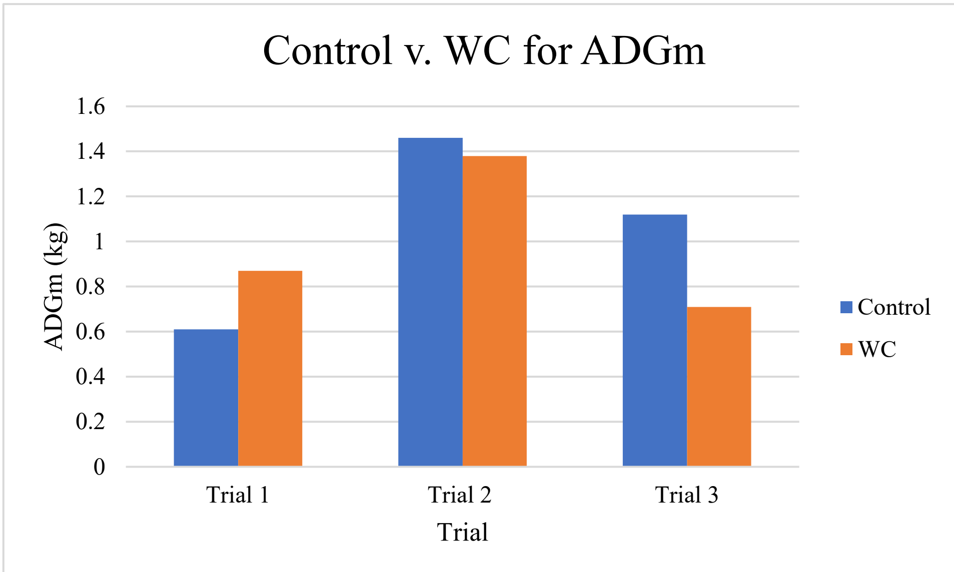

Figure 2: Control v. Whole Cottonseed on ADGm During Final 25-days

Total Average Daily Gain:

Total ADG was not affected by *(P* = 0.2*)* by treatment. During the 50-day trial duration, the average per kilogram weight gain each day was 0.77 kg/day amongst all treatments. Whole cottonseed diets gained a total average of 0.84 kg/day during the total 50-days. Control diets gained a total average of 0.70 kg/day, which is less than the average weight gain daily of whole cottonseed diets (Table 9, Figure 3). Base rations were offered as total mixed rations (TMR) and diets with the inclusion of whole cottonseed, were top-dressed with 1% whole cottonseed. Palatability issues were present within diets consuming whole cottonseed. During the first 25-days of the trials, weaned calves significantly picked through the whole cottonseed and as the second half of the trial began, palatability issues decreased, indicating that as the 50-day trial continued, weaned calves became adjusted to the TMR and the supplementation of whole cottonseed within their diet. Average daily gain increased in both diets as the ration increased 2.5%-3.5% BW over the course of the 50-days. As the calves were fed a higher % BW, the higher their average daily gain grew through the 50-day trials, indicating that as the weaned calves became more adjusted to the rations, the more they consumed and grew during the trials. Thus, as the % BW of the ration increased, so did the average daily gain and animal performance. Whole cottonseed diets did improve average daily gains between the three trials when breaking down the entire 50-days of the trial. Indicating the potential for beef cattle producers to improve average daily gains by adding whole cottonseed to a finishing ration. Whole cottonseed is an inexpensive feed ingredient and readily available through the United States. With the inclusion of whole cottonseed, beef producers can improve average daily gains and animal performance based upon the results of this study.

Total ADG was affected by trial *(P* = 0.005*),* with total ADG being greater for trial 1 compared with trial 3, trial 2 was intermediate and did not differ from the other two trials (Table 10, Figure 3).

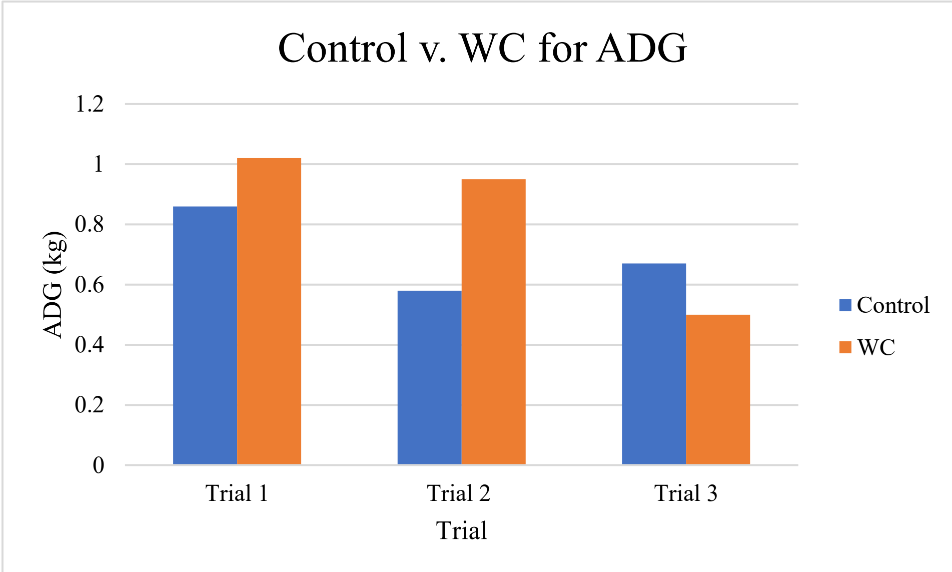

Figure 3: Control v. Whole Cottonseed on ADG During the 50-days

Economic Model

The primary goal of stocker production is to purchase or raise calves inexpensively and to sell them at a high cost. This goal creates profit for the beef producer. To create profit, the feed costs associated with average daily gain needs to be analyzed. For this study, 52 freshly weaned calves from three trial periods were fed at Western Kentucky's Feedlot with the goal of increasing average daily gain. The base ration was formulated with 23% cracked corn, 25% tall fescue hay, and 52% distillers' solubles. Half of the weaned calves were also supplemented with an additional 1% whole cottonseed to increase average daily gain. Whole cottonseed costs on average $0.02 per kg (CIM, 2020). Per Burkmann's Feed Store in Bowling Green, where the cracked corn is purchased by the bag, the cost per kg is $0.18. Western Kentucky Farm's records report on average the cost per kg of tall fescue hay is $0.07. Lastly, distillers' solubles vary in price depending on location and market but the average price per kg is $0.08

(Irwin and Good, 2013). The average weaning weight for all 52 calves was 258 kg. The base ration was fed at 2.5% BW each day. The average consumption daily based upon the average weaning weight was 6.44 kg/day.

To increase average daily gain and consumption, calves were fed at 2.5% BW daily. Half of the calves were supplemented with an additional 1% whole cottonseed. This additional 1% whole cottonseed fed to the average weaning weight was 2.58 kg/day within the feedlot ration. This $0.02 per kg cost for whole cottonseed would only equal $0.09 daily in additional costs from the base ration. The base ration would only cost $1.39 per head per day based upon the average weaning weight. The base ration with the additional whole cottonseed would cost $1.48 per head per day. The calculation includes 23% cracked corn at $0.59 per head per day, 25% tall fescue hay at $0.25 per head per day, and 52% distillers' solubles at $0.55 per head per day creating the $1.39 total. Over the 50-day trial period this total comes to $3,614 needed to feed the 52 calves. The additional whole cottonseed within the diet would only cost beef producers an additional $117 to supplement throughout the 50-day trial. This additional $117 has the potential to help producers increase average daily gain for their stocker calves at a cheap additional cost. This study showed that over the 50-day trial period, on average the calves consuming the whole cottonseed had a 0.14 kg/day higher ADG. This study showed the potential for whole cottonseed to increase ADG throughout the stocker phase of production. This additional whole cottonseed cost could help improve performance and weight gain in stocker calves over the typical 6-month stocker period. With a higher ADG, calves would sell for a higher price at market, creating a better return for the beef producer's investments within the herd. Thus, showing the potential and benefits of feeding whole cottonseed within the finishing phase of beef cattle.

Mixed Procedure Results

Table 9. Effect of Treatment on ADG, ADGs, and ADGm (kg/day)

Variable	Treatment 1	Treatment 2	SEM
ADG	0.7003	0.8247	0.2130
ADGs	0.3331[a]	0.6621[b]	0.3214
ADGm	1.0675	0.9872	0.2088

[ab]Within row, means without a common superscript differ ($P < 0.05$)

Table 10. Effect of Trial on ADG, ADGs, ADGm (kg/day)

Variable	Trial 1	Trial 2	Trial 3	SEM
ADG	0.9374[a]	0.7661[b]	0.5840[a]	0.2634
ADGs	1.1259[a]	0.1129[b]	0.2540[b]	0.3975
ADGm	0.7489[a]	1.4192[b]	0.9140[a]	0.2583

[ab]Within row, means without a common superscript differ ($P < 0.05$)

DISCUSSION

Upon completion of the three trials, additional changes could be made to help increase the significance of the results and to alter the model of the study. Cranston et al., in 2005 conducted a similar three trial study where they fed heifers and steers a control diet and a control diet with cottonseed components. This study utilized cottonseed meal, hulls, and oil (Cranton et al., 2005). They found that the control diet did not impact ADGs over the feeding periods. Cottonseed by-product diets created a higher ADG. This study helped show that feeding cotton by-products is safely done without adverse effects and helps to increases ADG (Cranston et al., 2005). Thus, in the future the WKU study could be redone replacing whole cottonseed with cottonseed by-products. Bagley et al., in 1988 conducted a cool-season annual forage study grazing beef steers on annual forages and annual/legume forage mixtures for evaluation on ADG's. They found that grazing steers on annual ryegrass had an ADG of 2.05 kg/day and grazing steers on annual ryegrass/clover had an ADG of 2.21 kg/day (Bagley et al., 2005). By utilizing a higher quality forage and reducing the number of distillers' solubles within the ration, the WKU study would have seen different results. Poore et al., in 2006 conducted a study on the performance of beef heifers grazing stockpiled fescue with supplementation of whole cottonseed. This study took forage samples weekly for analysis and nutrient breakdown. Thus, they found that heifers responded to the whole cottonseed supplementation while grazing stockpiled tall fescue, but performance and weight gain was much lower than expected (Poore et al., 2006). This low performance was significant considering the high quality tall fescue utilized within the study. Heifers fed the control diet did see increases in ADG based upon the higher quality fescue (Poore et al., 2006). A higher quality tall fescue could have impacted the results WKU study by increasing palatability and consumption of the ration. Lastly, Bretschneider et al., 2008 conducted a study on the effect of feeding antibiotic growth promoters on the beef cattle consuming forage diets. During this study, they found that cattle consuming ionophores like monensin and lasalocid increased ADG by 0.075 and 0.078 kg/day. This additional weight gain could have helped improve animal performance within the WKU. Further evaluation and research studies need to be conducted on the supplementation of whole cottonseed within the feedlot rations of stocker calves for improvements in average daily gains. The WKU study showed the potential and helped pave the way for whole cottonseed supplementation in the future, but additional studies should be conducted with varying research models to help improve significance and average daily gain.

CONCLUSION

In conclusion, the stocker phase of production is important for post-weaned calves. Allowing for freshly weaned calves to grow and gain weight under controlled conditions can help improve performance and minimize stress. Utilizing whole cottonseed within freshly weaned calves' diets, can increase weight gain and growth. Within all three trials, average daily gain increased throughout the 50-days. Base rations were calculated at 23% corn, 25% tall-fescue hay, and 52% distillers' solubles. Additional whole cottonseed was added to half of the weaned calves' diet at 1% BW. Whole cottonseed helped increase average daily gains during the first 25-days of the trials. The additional 1% of whole cottonseed helped increase average daily gain throughout the trials. During the first 25-days of the trials, whole cottonseed showed significance in increasing average daily gain. Whole cottonseed has excellent energy and protein content that is primarily utilized within dairy and beef finishing diets. Cottonseed is an inexpensive feed ingredient that has the potential to help beef producers increase profit margin without sacrificing average daily gains. Although whole cottonseed did not show any significance over the whole 50-day trials, ADG was slightly higher on average within the calves consuming the additional whole cottonseed. Thus, whole cottonseed should be considered a great nutritional addition to any finishing beef operation. Additional supplementation through feedlot rations can increase energy and weight for stressed calves during transitional time periods. The stocker phase of production can be very profitable for beef producers. Including whole cottonseed within their finishing rations could help increase profit when the stocker calves are sold.

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