Cotton Byproducts Assessment for Improving Beef Cattle Feeding Recommendations

by

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Abstract

Beef cattle producers in the southeastern US have access to byproducts from multiple industries, including the cotton ginning industry. These byproducts, specifically whole cottonseed and cotton gin trash, are subject to changes in nutrient quality and physical characteristics and as the cotton ginning industry advances in genetic selection to improve lint yield and ginning processes. These changes warrant periodic evaluation of the byproducts available to beef cattle producers to update feeding recommendations. A series of experiments were conducted to evaluate beef cattle whole cottonseed feeding recommendations, gossypol intake, protein utilization characteristics, and gin trash feeding strategies. A whole cottonseed intake study using a crossover design in the Calan Gate® system was conducted to evaluate intake differences between a commonly grown cottonseed variety, DP1646, and a low-gossypol cottonseed variety, ULGCS. Six Angus-cross calves (two steers and one bull per group, average BW = 281 kg) were assigned to two treatments: 1) *ad libitum* DP1646 and bermudagrass hay, and 2) *ad libitum* ULGCS and bermudagrass hay. Each group underwent a 7-day acclimation period followed by a 7-day intake measurement period. Groups were then crossed over to the opposite treatment for a second acclimation and intake measurement period. Cattle consuming ULGCS had a greater ($P = 0.0011$) intake than cattle consuming DP1646. Cattle consuming ULGCS also had less total gossypol intake ($P < 0.0001$), and less free gossypol intake ($P < 0.0001$) compared to cattle consuming DP1646. An *in situ* digestibility study was conducted to evaluate potential digestibility differences between DP1646 and ULGCS. Two ruminally-cannulated steers were allowed free-choice access to whole cottonseed for a 7-day acclimation period prior to the start of the trial. Greater ($P < 0.0001$) ruminal DM digestibility was observed

for ULGCS than for DP1646. Ninety-eight cotton varieties and breeding lines were obtained from the Auburn University Cotton Breeding Program and analyzed for relative distribution of degradable intake protein (DIP) to determine potential variation among cotton seed from a beef cattle feeding perspective. The varieties and lines tested had a range of DIP from 36.01% to 73.99% of total CP. A 60-day gin trash intake study was conducted using the Calan Gate® system to determine potential intake and animal performance differences between loose and baled gin trash. Twenty-four non-lactating crossbred cows and heifers (average BW = 613.41 kg) were assigned to one of two treatments: 1) *ad libitum* baled gin trash with 2.27 kg of 50:50 corn gluten feed and soybean hull pellets per day and 2) *ad libitum* loose gin trash with 2.27 kg of 50:50 corn gluten feed and soybean hull pellets per day. Body weight and body condition scores were collected at days 0, 30, and 60 of the study. Cattle consuming loose gin trash had a greater ($P < 0.0001$) intake than cattle consuming baled gin trash. Overall daily DM intake was close to 2.0% of animal body weight during the trial. There were no differences ($P \geq 0.6962$) in body weight between gin trash feeding treatments or days of study. Throughout these studies, it was observed that whole cottonseed and gin trash can be used to support beef cattle at various stages of production if utilized correctly.

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List of Abbreviations

ADF	Acid Detergent Fiber
ADG	Average Daily Gain
BCS	Body Condition Score
BW	Body Weight
CP	Crude Protein
DIP	Degradable Intake Protein
DM	Dry Matter
DMI	Dry Matter Intake
HCT	Hematocrit
HGB	Hemoglobin
NDF	Neutral Detergent Fiber
RBC	Red Blood Cell Count
TDN	Total Digestible Nutrients
UIP	Undegradable Intake Protein
US	United States
WBC	White Blood Cell
WCS	Whole Cottonseed

I. Introduction

Cotton production provides beef producers with a variety of byproducts that can be included into beef cattle diets such as whole cottonseed, cottonseed hulls, cottonseed meal, and gin trash. The USDA NASS Crop Production 2020 Summary reported 8.5 million acres harvested, generating approximately 14.4 million 218.2-kg bales of cotton and 4.5 million tons of whole cottonseed (USDA NASS, 2021). The amount and feed characteristics of the byproducts generated from cotton production warrants further exploration of inclusion potential for beef cattle production.

Whole cottonseed can be used to supply both energy and protein in beef cattle diets (Stewart and Rossi, 2010). Whole cottonseed nutrient concentrations can vary depending on the selection pressures placed on the specific varieties by cotton breeders, potentially altering the utilization of nutrients by beef cattle (Bertrand et al., 2005). Inclusion in beef cattle diets is typically limited to 0.33% of body weight and 0.5% of body weight for growing and mature cattle, respectively. This limitation is primarily to limit fat intake in order to maintain rumen function and prevent gossypol toxicosis. Gossypol is a polyphenolic compound that can potentially have negative impacts on reproduction (Rogers et al., 2002). Selection pressures have also been applied to some cotton breeding programs to reduce or remove gossypol from the cotton plant or specifically from the cottonseed in an effort to increase food and feed uses of cottonseed (Vroh Bi et al., 1999).

Cotton gin trash is another byproduct of cotton production with potential for inclusion in beef cattle diets as a roughage source for growing cattle or as a replacement for low- to medium-quality hay in times of drought or hay shortage for cattle with low energy requirements such as non-lactating cows. Inclusion in growing beef cattle diets is typically restricted by the low energy concentration. For each 218.2-kg bale of cotton, approximately 68.2 kg to 90.9 kg of gin trash is produced (Stewart and Rossi, 2010). Gin trash is a low-value byproduct with transportation commonly being the greatest cost associated with utilization in beef cattle diets due to its low bulk density. Because of the low monetary value and amount produced by the ginning process, many gins simply pile the gin trash outside exposed to weather, which can lead to mold, reduced palatability, and decomposition (Rogers et al., 2002; Stewart and Rossi, 2010). Some gins have begun baling gin trash. The baling process compacts the gin trash, which increases the bulk density and makes it easier to handle and store, potentially preserving nutritive value if stored inside. Another consideration regarding the inclusion of gin trash in beef cattle diets is that tolerance levels for pesticide residue have not yet been established.

The objectives of these projects were to evaluate the use and safety of cotton byproducts, whole cottonseed and cotton gin trash, for inclusion in beef cattle diets across different stages of production to update extension feeding recommendations and account for changes in feeding characteristics arising from cotton breeding efforts and gin trash processing methods.

II. Literature Review

Supplementing Beef Cattle

Beef cattle producers throughout the Southeast are continually faced with multiple management decisions, a major one being feed supplementation strategy for the herd. Supplementing beef cattle on forage-based diets is a practice commonly used to conserve forage, meet animal nutrient requirements that the forage alone cannot provide, increase animal performance, increase economic return, and modify animal behavior (Kunkle et al., 2000). In order to accurately develop a supplementation strategy, the producer must determine the stage of production and nutrient requirements of cattle, the amount of nutrients provided by the forage, and identify a supplementation strategy that will bridge the gap between available and required nutrients that best fits the individual system (Lalman, 2004).When supplementing beef cattle, the two major strategies are to either supplement energy or protein, which tend to be the first most limiting nutrients in Southeastern beef cattle diets. The strategy chosen must meet production goals for the operation in an economical manner. Each supplementation strategy can be used to bridge the nutrient requirement deficit for different situations.

DelCurto et al. (2000) states that as the digestibility of forages decrease, protein available to the rumen microbial population and the host animal also decreases. If a low-quality roughage is not limited in availability and intake, beef cattle will benefit more from protein supplementation than from energy supplementation. Moore and Kunkle (1998) reported that in low-quality forages when the TDN:CP is greater than 7, voluntary intake is depressed due to a protein deficit. By supplementing protein to narrow the TDN:CP, intake will increase. Ruminants consuming low quality forages, typically below 6 to 7% CP, are primarily limited by NH_3-N, which limits ruminal microbial fermentation capacity. Supplementing protein instead of energy in this situation can alleviate the primary N limitation of the rumen microbial population (Horn & Mccollum, 1987). By increasing supplemental protein on low-quality forage diets, both dry-matter intake and digestibility have been shown to increase (Bohnert et al., 2011).

Several studies have reported that feeding frequency of protein supplements can be altered without affecting performance. Most of these studies evaluated protein supplementation frequency in native forage systems in the midwestern US. Wettemann and Lusby (1994) reported that feeding equal amounts of protein supplement 3 days a week instead of 6 days had no influence on body condition score loss or body weight loss for the 123 mature spring calving beef cows used in this study. In a study by Farmer et al. (2001), cattle received a high-protein supplement (43% CP) at varying supplementation intervals (daily to twice a week). Although cows lost body condition across all treatments when fed for a 90-day period, the authors reported that supplementation interval had no effect on calf birth weights. However, cow weight loss was less for cows supplemented every 7 d compared with those supplemented 2 d per week. Many producers will implement this reduced-frequency supplementation strategy to reduce labor costs and avoid excessive trips to areas that are difficult to access. Interval feeding has also been shown to improve supplement intake of less aggressive or timid cows (Lalman, 2004) and reduce grazing pattern disruption (Kunkle et al., 2000).

Supplementing cows with energy is generally used to increase animal performance from low-quality roughage, or to conserve forage (Kunkle et al., 2000). In the Southeast, energy is often considered the more limiting nutrient in winter feeding systems for cows than protein due to energy demands of the stage of production and forage availability. Fall-calving cows are lactating and trying to re-breed, whereas spring-calving cows are entering the third trimester of pregnancy. Cows in both calving systems are experiencing increased nutrient requirements and commonly relying on hay alone to meet these needs. Energy supplementation strategies will typically utilize one of two types of energy supplement, a high-starch energy supplement or a low-starch energy supplement. High-starch energy supplements are typically cereal grains, such as corn, and used in finishing rations for feedlot cattle. These types of supplements can decrease the cellulolytic bacteria population in the rumen, decreasing ruminal pH, forage intake, and fiber digestion (Loy et al., 2007). Low-starch energy supplements rely on highly digestible fiber or fat to supply energy for cattle. Common low-starch supplements include many byproducts from grain processing such as corn gluten feed, dried distiller's grains plus solubles, or soybean hulls. These products are able to supply energy to supplementation programs, but do not contribute roughage or physically effective neutral detergent fiber (NDF) for cattle (Benton et al., 2007).

Altering feeding frequency of energy supplements may support more variable performance responses in various classes of beef cattle than interval feeding of protein supplements. A study by Moriel et al. (2012) reported that decreasing the feeding frequency of energy supplements had negative performance and reproductive effects on beef heifers receiving low- to mid-quality forage being supplemented low-starch energy, and should receive supplement daily instead of every 3 days. Another study by Cooke et al. (2008) demonstrated that heifers consuming low-quality forage supplemented with low-starch energy sources had greater growth rates and improved pregnancy rates when supplemented daily compared with every 3 days. However, stocker cattle consuming medium-quality hay and supplemented with soyhulls and corn gluten feed daily, three days a week, or twice a week resulted in increased average daily gain when compared with non-supplemented steers. Feed-to-gain ratios were improved for steers receiving supplement, with a further increase for steers supplemented less frequently. (Drewnoski et al., 2011). Drewnoski and Poore (2012) reported that beef steers receiving a soybean hull/corn gluten feed blend at 2% BW on alternate days compared with daily supplementation at 1% BW showed no difference in DM digestibility or N retention. Steers receiving supplementation on alternate days had reduced hay intake compared to steers receiving daily supplementation, potentially due to increased gut fill from the supplementation event.

Several studies have evaluated frequency of energy supplementation at defined time periods in the cow production cycle and its impacts on cow-calf performance. A study by Moriel et al. (2016) utilizing 28 multiparous spring-calving Angus cows fed ground fescue hay *ad libitum* and supplemented to provide energy with wet brewers grains daily or 3 times weekly pre-partum reported that gestation length and cow body weight (BW) and body condition score (BCS) at parturition were not affected by low-starch energy supplementation frequency. Overall forage intake was not affected by supplementation frequency; however, hay intake for cows supplemented 3 times per week was decreased on days supplement was offered whereas cows receiving supplement daily had consistent hay intake throughout the study. Calf birthweight, 205-d adjusted BW and average daily gain (ADG) did not differ due to supplementation frequency of cows, suggesting that frequency of low-starch energy supplementation can be manipulated to reduce cow-feeding costs without affecting cow or calf performance. Moura et al. (2020) reported that frequency of energy supplementation both pre- and post-partum in primiparous Nellore cattle did not alter cow or calf performance.

Byproduct Feeds

Byproducts can be an economical source of supplement for beef cattle. Byproducts are secondary products derived from primary product processing such as food or fiber production. Cow-calf and stocker producers in the Southeast have access to a variety of byproducts from multiple agricultural product processing methods. The biggest draw-back to many of these byproducts is the variability of nutrient concentration between processing plants and within different byproduct lots from the same plant (Simms, 2009). Theses variations can alter many aspects of the feed such as palatability and nutrient concentration. Because of this, a nutrient analysis of the byproduct is recommended to ensure the quality and nutrient concentration of the feed.

Cattle producers can utilize byproducts from various industries. Brewer’s grains, derived from the beer industry, are a good protein and energy source that is palatable to cattle and can be obtained wet or dry. Wet brewer’s grains must be fed soon after production to avoid spoilage. Brewers grains have a high percentage of rumen undegradable protein, making them a good supplement choice for calves or cattle consuming low-quality forages. Corn gluten feed (CGF) is a byproduct of corn syrup production that provides a low starch, moderate protein supplement for cattle. Distiller’s dried grains with solubles (DDGS) is a byproduct of the wet milling process of the alcohol industry that is dried to achieve ease of transportation. DDGS is a palatable, high-protein, high-energy byproduct, but is commonly overheated when dried, reducing the availability of the protein, and reducing palatability. Avoid dark DDGS when possible, which may indicate the product has overheated and can have negative implications on feed quality. Distillers grains with solubles (DGS) is derived from the ethanol industry and is typically sold wet, which limits the feasibility of long-distance transport and storage duration. DGS have similar characteristics of DDGS but have a greater feed value. Peanut hulls are the hulls left behind after the peanuts have been shelled. They are a coarsely ground, bulky, low-digestible fiber source with low-palatability, and inclusion into rations is typically low. Peanut skins are a high-fat, medium-protein, high-tannin byproduct of peanut processing. The elevated tannin concentration of peanut skins can decrease the digestibility of available protein. Soybean hulls are derived from the oil extraction of soybean. Soybean hulls have no starch but high energy content due to highly digestible fiber, making them a good supplement option for cattle consuming low-quality forages. However, soybean hulls are low in protein and can potentially cause bloat when fed at high levels (Simms, 2009).

Cotton Byproducts

In 2020, the United States planted over 5.5 million hectares, and harvested over 3.4 million hectares of cotton, producing more than 14.4 million 218.2-kg bales (USDA NASS, 2020). Of the acreage planted, 5.4 million hectares was planted in Upland cotton with the remainder being Pima cotton. Each 218.2-kg bale produces approximately 335.7 kg of seed and 68-91 kg of cotton gin trash (Stewart and Rossi, 2010). Because of this, cotton production provides a large amount of potential feedstuffs that can be utilized by cattle producers, such as cottonseed meal, cottonseed hulls, gin trash, and cotton gin motes.

Cottonseed meal is generally produced by mechanical, prepress and solvent, or direct solvent extraction. Regardless of the process, the nutritive value is similar (Goetsch & Owens, 1985). Cottonseed meal is a commonly used protein supplement containing around 45% CP that is typically cheaper than soybean meal because the gossypol levels present in the cottonseed meal limit its use for swine and poultry (Rogers et al., 2002). Cottonseed meal has been shown to be an adequate replacement for soybean meal because of its similar protein degradability. It can be mixed with salt at a 2:1 ratio to limit intake for mature cows or mixed at approximately 10% salt for a high protein creep feed supplement. It can also be cubed or pelleted, producing cottonseed cake (Rogers et al., 2002).

Cottonseed hulls are a byproduct of cottonseed meal production that have a high fiber and low nutrient concentration but are readily accepted by and palatable to cattle. Cottonseed hulls are commonly used as roughage source for preconditioning diets, intake limiters for self-feeders, and roughage source for feedlot diets. Cottonseed hulls have been shown to slow rumen passage and alter digestion of other diet ingredients (Rogers et al., 2002). Because of their high fiber concentration, they are a more effective roughage source in high-grain diets than alfalfa hay or silage. Cottonseed hulls should not exceed 50% of the diet to ensure adequate performance. Due to their low bulk density and minimum nutrient concentrations, use of cottonseed hulls are limited to areas near production plants (Stewart and Rossi, 2010).

Gin Trash

Gin trash is a byproduct of the cotton industry that goes by multiple names; e.g., gin trash, cotton gin trash, or cotton burrs. Gin trash is composed of the foreign material remaining from the ginning process such as leaves, dirt, stems, boles, burs, lint, and cottonseed that is not separated out (Myer, 2007). Gin trash is typically a low-value byproduct that, as the name suggests, is generally viewed as waste to be disposed of at landfills or composted and applied to fields for soil amendment. The low bulk density limits the economic feasibility to transport long distances, so use is typically restricted to areas surrounding gins.

Nutrient composition of gin trash varies among gins due to different ginning processes, as well as storage and handling. It is common practice for gins to wet gin trash to reduce dust and even hasten the decomposition process, which can potentially lead to mold, decrease palatability, or cause the gin trash to undergo a heat and decrease the nutritive value (Stewart and Rossi, 2010). Some gins in the Southeast have begun baling gin trash in the last five years. Baled gin trash is similar to loose gin trash; however, as it is processed into bales, some finer material is lost, increasing the concentration of lint, seed, and hulled material, generally resulting in greater

TDN and CP concentrations. Bales are typically 227 to 272 kg, which increases the density of the gin trash making it easier to transport.

Whole Cottonseed

Whole cottonseed is primarily utilized as a source of supplemental protein and energy. It is also a good source of fiber and phosphorus but is low in calcium (Rogers et al., 2002). On a dry matter basis, whole cottonseed contains 22.8% CP, 19.5% fat, 93% TDN, 47.8% NDF, 0.53% P, and 0.22% Ca (NRC, 2016). A feed analysis should be performed to accurately determine the nutritive value of whole cottonseed since quality will vary based on cotton variety, growing season conditions, ginning and storage procedure prior to feeding. Feeding whole cottonseed provides a similar nutritive response as feeding an equal amount of cottonseed hulls, meal, and oil (Moore et al., 1986). Rogers et al. (2002) state that the CP in whole cottonseed is "true protein" and is better used for supplementing high-forage diets than non-protein nitrogen sources such as urea. The protein in whole cottonseed is primarily located in the heart of the seed, encased in the hull, and mixed with fat that slows its release into the rumen.

Cotton breeders have done extensive work to produce vigorous and viable seed to help ensure adequate stand establishment in cotton crop production systems. Some parameters of interest are the seed constituents, seed size, and gossypol concentration. Seed constituents such as protein and oil reserves support the growth of the cotton plant until it is photosynthetically active (Turley and Chapman, 2010). The protein and oil reserves also influence the nutritive value of whole cottonseed when utilized as a supplement to cattle. Seed size is another focal point of many cotton breeders. Large seed size has been related to increased seedling vigor due to greater oil and protein reserves; however, smaller seeded cotton varieties have been selected for to increase lint yield and lint percent (Snider et al., 2016). Smaller seed size may also result in decreased exposure to mastication and decreased seed digestibility when fed to cattle (Bertrand et al., 2005). Work has also been done to reduce gossypol concentration in cottonseed to allow its safe use as a feed source for both humans and animals (Vroh Bi et al., 1999). Glandless or gossypol-free cotton has been developed to produce non-toxic cottonseed but removing the gossypol from the entire plant often leads to insect predation. This has led to the development of high-gossypol cotton plants with low-gossypol cottonseed (Vroh Bi et al., 1999).

The fat content of whole cottonseed is the primary source of energy and the primary limiting factor of supplementation amounts. Fat intake should be limited to 4.0% of total diet, this restriction is met by feeding cattle no more than 0.5% of body weight or 20% of the total diet (Rogers et al., 2002). If fed at recommended levels, whole cottonseed will not interfere with digestion due to the energy being from fat instead of starch.

Another limiting factor affecting the inclusion of cotton byproducts into cattle supplementation programs is gossypol. Gossypol is a yellow pigmented, polyphenolic aldehyde produced by glands throughout the cotton plant to help protect itself from predation (Zhang et al., 2007). Gossypol is found in two isomers, the (-) isomer, or free gossypol, and (+) isomer, or bound gossypol. Free gossypol is the more biologically active and toxic form. Bound gossypol is attached to an amino acid and is considered non-toxic. However, a study by Noftsger et al. (2000) reported that dairy cows consuming high levels of extracted-expelled cottonseed had higher levels of plasma gossypol than cows fed whole cottonseed. The extracted-expelled cottonseed had a lower concentration of free gossypol than whole cottonseed but showed that bound gossypol can be broken down into free gossypol in the rumen. Gossypol is a highly reactive compound that easily binds to amino acids. Gossypol can also readily bind to iron, making it unavailable to the animal and potentially causing an iron deficiency effecting hematopoiesis (Nunes et al., 2010).

Nonruminants and pre-ruminants are more susceptible to gossypol than functioning ruminants that are able to detoxify free gossypol by binding it to proteins (Nunes et al., 2010) Gossypol toxicosis typically results from prolonged exposure to high levels of free gossypol that overload the detoxifying capacity of the rumen, causing free gossypol to be directly absorbed by the animal in the small intestine. The effects of gossypol toxicosis are more prominent in male ruminants, mainly affecting sperm production and motility by decreasing testosterone concentrations and damaging spermatogenic epithelium (EL-Mokadem et al., 2012). Hassan et al. (2004) showed that bulls fed a ration containing gossypol had a significant increase of both primary and secondary sperm abnormalities, but these effects were reversible when the bulls were transitioned back to a gossypol free-ration.

Gossypol concentration is influenced by several factors including weather conditions, cotton species, and cotton variety within species (Nunes et al., 2010) Pima cotton (*Gossypium barbadense*) has greater fat and protein concentrations than Upland cotton (*Gossypium hirsutum)* which has greater fiber concentration and rumen degradability (Zhang et al., 2007). Whole cottonseed derived from Pima cotton has greater concentrations of free gossypol than cottonseed from Upland varieties with reported ranges of 24.9 to 68.9% and 33.8 to 47.0%, respectively (Gadhela et al., 2014).

Protein Utilization by Ruminants

The CP portion of a feedstuff can be further broken down to degradable intake protein (DIP) or undegradable intake protein (UIP). These protein fractions are characterized by the location and process by which they are broken down and utilized. The DIP fraction is broken down into carbon skeletons and ammonia in the rumen, the ammonia is then used to support the microbial population and to generate microbial protein. As rumen microbes are flushed out of the rumen, they enter the small intestine and are broken down and utilized by the host animal. To maximize forage utilization and intake adequate amounts of DIP, approximately 8 to 13 % of the total digestible organic matter, must be consumed to support rumen microbial function (Mathis et al., 2000). Common examples of high-DIP feeds, DIP concentrations above 50 %, are wheat middlings and soybean meal (NRC, 2016). The UIP fraction is dietary protein that is not degraded by the rumen microbes and is broken down directly by the host animal in the small intestine by enzymatic degradation, supplying proteins and amino acids. Supplementation of UIP is commonly used after the DIP requirement is met to increase performance of growing animals. Feeds high in UIP are dried distillers grains, corn gluten meal, and blood meal (Lalman, 2004).

Beef cattle producers in the Southeast typically have access to a variety of protein supplements such as corn gluten feed and DDGS. Corn gluten feed, on average, has 22.6% CP with approximately 63.69% DIP. Dried distillers grains with solubles has a greater average CP value, 30.8%, but only approximately 32.0% DIP (NRC, 2016). Compared with the common protein supplements listed above, whole cottonseed, on average has 22.9% CP (NRC, 2016); however, information on protein degradability characteristics of whole cottonseed are not as readily available. A review by Arieli (1998) reported a rumen CP degradability value of 70% for whole cottonseed from three separate studies. As a result of cotton breeding selection pressures, seed characteristics and constituents have been altered, potentially changing digestibility characteristics (Bertrand et al., 2005).

Beef Cattle Performance Responses from Whole Cottonseed Supplementation

Whole cottonseed is commonly fed to beef cattle consuming hay to supplement both protein and energy. A study by Hill et al. (2008) compared cow and calf performance of 78 beef cows pre- and post-partum consuming bermudagrass hay, hay plus a commercial hot-poured protein tub, and hay plus whole cottonseed at 0.5% of bodyweight. Cows consuming whole cottonseed gained body weight and condition compared with cows fed hay only or hay and supplementation through consumption from a free-choice protein tub (24% CP). Calf weights tended to be greater for calves in the whole cottonseed treatment than calves in the protein tub supplementation program. Another study by Hill et al. (2009) evaluated non-lactating, non-pregnant cows receiving 0.25% of BW, 0.5% BW, or free-choice whole cottonseed supplement for 63 and 70 d in year one and year two, respectively, and demonstrated that cows allowed free-choice access can consume well above the recommended amount (0.5% of BW), which negatively affect digestion because of increased fat intake, and can increase supplementation cost. Allowing free-choice access can also result in greater waste due to trampling or rain.

Heifers grazing stockpiled tall fescue and supplemented with whole cottonseed at 0.33% of BW and 0.2 kg of a corn and soybean meal mix per day had a greater ADG and BCS than heifers strictly grazing stockpiled tall fescue. The corn and soybean meal mix was added to encourage consumption of whole cottonseed. By supplementing heifers grazing stockpiled tall fescue with whole cottonseed, adequate gains were achieved to reach targeted body weight and condition (Poore et al., 2006).

It is generally recommended to not feed bulls whole cottonseed 60 to 90 days prior to the start of breeding season as a precaution, but bulls consuming whole cottonseed during the breeding season is not a concern. Any potential fertility effects of gossypol toxicosis often take several months to develop (Myer and McDowell, 2003). A study by Chase et al (1994) evaluated the effect of gossypol on growth and reproductive development in Brahman bulls. In this study, bulls were fed diets containing cottonseed meal, whole cottonseed, or soybean meal. Bulls consuming whole cottonseed received approximately 10 times the amount of free gossypol as bulls consuming cottonseed meal, and the whole cottonseed diet contained 41.4% whole cottonseed, roughly twice the recommended feeding level. No differences were observed between groups for scrotal circumference or semen quality. These studies indicate that whole cottonseed, with appropriate management, can be effectively used as a component in the diets of various classes of beef cattle and production stages.

Beef Cattle Performance Responses from Gin Trash Supplementation

Cotton gin trash is a byproduct of the cotton ginning process that can be utilized as a low-quality roughage source for beef cattle in times of limited forage availability or hay shortage. A study by Kennedy and Rankins (2008) compared the performance of steers consuming gin trash with cracked corn, gin trash with cracked corn and cottonseed meal, peanut hulls with cracked corn, and peanut hulls with cracked corn and cottonseed meal. Steers fed gin trash-based diets experienced greater DMI, dry-matter digestibility and ADG than steers fed peanut hull-based diets. Gin trash can also be used as a roughage source for feedlot diets (Rogers et al., 2002). A study by Warner et al. (2020) evaluated the use of cotton byproduct use in a finishing diet, including gin trash as a roughage source to replace prairie hay, indicated that steers consuming the cotton byproduct diet had greater DMI hot carcass weight, and fat thickness as compared to steers receiving the control diet, but no differences in marbling or ribeye area were observed. Dry beef cows with a body condition score of 5 or greater can be maintained on diets containing primarily gin trash, but often require some form of energy supplementation due to the limited amount of available TDN. This is likely due to dry cows having the lowest nutrient requirements of any production stage of beef cattle (Stewart and Rossi, 2010).

Summary

Cotton byproduct feeds are readily available for use in southeastern beef cattle systems. Whole cottonseed is widely used as an energy and protein supplement, but gossypol levels in seed may impact feeding practices in beef operations. Protein characteristics of whole cottonseed are not well defined, only crude protein values are often reported in the published literature. Cotton gin trash represents one of the greatest waste products of cotton processing, but bulk density of loose trash limits transport distance potential. Evaluation of beef cattle performance utilizing cotton byproducts, specifically whole cottonseed and gin trash, is needed to account for genetic changes in cotton and newly implemented processing methods in order to update current extension feeding recommendations.

III. Evaluation of whole cottonseed intake, *in situ* digestibility, and protein degradability for use in beef cattle diets

Introduction

Whole cottonseed is a byproduct of the cotton industry that is commonly utilized as both a protein and energy supplement for beef cattle. Commercially-released cotton varieties or breeding lines for agronomic production have varying ruminant livestock feeding values such as concentration of protein, energy, and gossypol, and periodic evaluation of the diversity in byproduct feed resources is needed to validate current Extension feeding recommendations. Genetic selection to increase cotton lint yield and lint percent often lead to selection for smaller seed size, whereas selection for seedling vigor typically favors large seed size to increase oil and protein reserves present in cottonseed (Snider et al., 2016). Cotton breeding efforts have been made to reduce the total amount of gossypol, a polyphenolic compound that is found throughout the cotton plant and can have a negative impact on reproductive performance in bulls fed whole cottonseed (EL-Mokadem et al., 2012). Southeastern beef cattle producers often express concern for using whole cottonseed in cow-calf operations during breeding season or as part of bull development rations due to gossypol (Mullenix, personal communication, 2021). However, gossypol intake levels of whole cottonseed in beef cattle systems is not widely reported and work was conducted more than 25 years ago with seed derived from cotton varieties no longer used in commercial row crop production systems (Randel et al., 1992; Chase et al., 1994). Protein utilization may also be improved for use in beef cattle by selecting cotton lines with greater proportions of undegradable intake protein (UIP or 'bypass protein'). A shift towards a more balanced proportion of degradable intake protein (DIP) and UIP may increase cottonseed value from a ruminant feeding perspective by increasing nutrient utilization. These selection pressures can influence the feeding values and animal nutrient use efficiency of whole cottonseed in beef cattle systems (Bertrand et al., 2005), and protein degradability characteristics are not reported for use by the animal science academic community in the current Nutrient Requirements of Beef Cattle Publication (2016).

The objectives of this study were: 1) determine intake potential of a low-gossypol (ULGCS) cottonseed vs. commonly grown variety (DP1646) cottonseed in growing beef steers and bulls to extrapolate intake potential across various classes of beef cattle, 2) determine potential *in situ* digestibility differences of a low-gossypol (ULGCS) cottonseed and a commonly grown variety (DP1646) cottonseed using cannulated steers, and 3) quantify concentrations of DIP and UIP in currently used cotton varieties and Auburn University breeding lines.

Materials and Methods

Research Site

A feed intake trial was conducted at the Auburn Bull Test and Evaluation Center, Auburn, Alabama. The *in situ* digestibility trial was conducted at the E.V. Smith Research Center Beef Unit, Shorter, Alabama, and all associated laboratory analyses being conducted at the Auburn University Ruminant Nutrition Laboratory, Auburn, Alabama. All experimental procedures for the project were reviewed and approved by the Auburn University Institutional Animal Care and Use Committee (2019-3616).

Intake Trial Experimental Design

Six Angus and Angus-cross calves (average BW 281 kg; 4 steers and 2 bulls) were randomly assigned to 2 groups consisting of 1 bull and 2 steers each in a crossover design. Calves were trained to the Calan Gate® system (American Calan, Northwood, NH), then each group was assigned to one of two diets: 1) *ad libitum* DP1646 whole cottonseed or 2) *ad libitum* ULGCS whole cottonseed. Each treatment group was provided free-choice access to bermudagrass hay. Calves were allocated to their respective treatment groups for a 7-day acclimation period followed by a 7-day measured intake period. Groups were then switched to the second diet, again with a 7-day acclimation period followed by a 7-day measured intake period. Orts were weighed each morning and recorded during the trial. Body weights were recorded on days 0, 7, 14, 21, and 28 of the study. Whole cottonseed from DP1646 was obtained from Milstead Farm Group Inc (Shorter, AL). Seed from ULGCS was obtained from the USDA ARS Southern Regional Research Center in New Orleans, LA. Samples of both DP1646 and ULGCS were collected via grab sampling from each seed batch and analyzed for total gossypol, free gossypol, and nutritive value parameters by Cumberland Valley Analytical Services (Waynesboro, PA) that are presented in Table 1. Hay samples were collected and analyzed for nutritive value analyses by Auburn University Soil Testing Laboratory (Auburn, AL). Hay used during the present study contained 8.6% CP, 56.7% TDN 79.9% NDF, and 41.4% ADF.

Table 1. Nutritive value parameters (% DM basis) of whole cottonseed varieties used in a beef cattle intake trial and *in situ* digestibility study.

Cotton Variety	Dry Matter (%)	Crude Protein (%)	Crude Fat (%)	Total Digestible Nutrients (%)	Total Gossypol (%)	Free Gossypol (%)
DP1646†	90.4	22.9	16.4	77.8	0.73	0.53
ULGCS	92.8	23.7	19.3	84.8	0.17	0.072

†Delta Pine 1646 (DP1646); Ultra Low Gossypol Cottonseed (ULGCS).

In Situ Digestibility

Two ruminally-cannulated steers located at E.V. Smith Research Center Beef Unit were used for the determination of *in situ* digestibility of ULGCS and DP 1646 whole cottonseed. The steers had *ad libitum* access to whole cottonseed and bermudagrass hay for 7 days prior to data collection. Whole cottonseed was frozen with liquid nitrogen and ground to pass a 1-mm screen using a Wiley Mill. One gram of the ground cottonseed was weighed into a nylon *in situ* bag (pore size 50 μm; Ankom Technology, Macedon, NY). *In situ* bags were pre-incubated in hot water (39°C) for 20 minutes prior to entering the rumen. All samples for each time period (0, 2, 4, 6, 12, 24, 48, and 72 h) were placed in polyester mesh bags and connected to a stainless-steel chain (Vanzant et al., 1998) to ensure all samples would remain below the forage mat in the ventral sac of the rumen. All bags, except time point 0, entered the rumen at the same time, and were removed at the corresponding time point and frozen (0°C) until analysis. Time point 0 bags were not inserted into the rumen but were pre-incubated in hot water for 20 minutes before freezing (0°C).

Following thawing, bags were rinsed at 39°C in an agitating water bath for 5 min at 110 rotations per minute (rpm; Whittet et al., 2002). Bags were then rinsed individually with distilled H_2O and dried at 55°C for 48 h in a forced air oven. Neutral detergent fiber concentration was determined according to the method of Van Soest et al. (1991).

Protein Degradability

Ninety-eight cotton varieties and breeding lines were obtained from the Auburn University Cotton Breeding Program and analyzed for protein degradability to evaluate variation in DIP/UIP concentration in whole cottonseed protein concentration. A list of cotton varieties and lines evaluated is provided in the Appendix. Degradable intake protein of whole cottonseed was analyzed using a *Streptomyces griseus* protease procedure (Type XIV Bacterial; Sigma-Aldrich, Co., St. Loius, MO) as described by Mathis et al. (2001). Samples were analyzed for total N concentration using the Kjeldahl Analyzer Unit Foss Tecator (Hogans, Sweden). Based on this assay, each sample was weighed out to obtain 15 mg of N based on N concentration of the sample and placed in 125 mL Erlenmeyer flasks. Forty mL of a borate-phosphate buffer solution was added to each flask and incubated at 39°C for 1 hr in a shaker water bath. After incubation, 10 mL of protease solution was added to each flask and incubated for 16 h at 39°C in a shaker water bath. Following the 16-h incubation, samples were filtered through Whatman #540 filter paper using a cone shaped funnel and rinsed with 400 mL of distilled H_2O to remove any incubation media. Samples were then dried in a 100°C oven for 24 h to obtain residual DM weight. Samples were analyzed for N using the Kjeldahl Analyzer Unit Foss Tecator (Hogans, Sweden). Percentage UIP was calculated by dividing the mg of residual N by the mg of initial N and multiplying by 100. Percentage DIP was calculated by subtracting percentage UIP from 100 for each sample.

Statistical Analysis

Whole cottonseed intake and *in situ* digestibility were analyzed using PROC MIXED of SAS 9.4 (SAS Inst., Cary, NC). Protein degradability characteristic data were analyzed using PROC ANOVA of SAS 9.4 (SAS Inst., Cary, NC). Cotton variety was considered the independent variable for all studies. Whole cottonseed intake dependent variables were individual animal intake, total gossypol intake, free gossypol intake, and nutrient values of whole cottonseed. *In situ* dependent variables were digestibility, timepoint analyses, and nutrient value of the cottonseed. Protein degradability dependent variables were total CP and DIP. Treatment means were separated using the DIFF option of the LSMEANS procedure (SAS Inst., Cary, NC) and were determined to be significant when $\alpha = 0.05$.

Results and Discussion

Whole Cottonseed Intake

When comparing whole cottonseed intake across treatment groups, cattle consuming ULGCS had greater ($P = 0.0011$) intake than cattle consuming DP1646. The average daily intake for cattle consuming ULGCS was 2.2 ± 0.2 kg. The average daily intake for cattle consuming DP1646 was 1.1 ± 0.2 kg (Figure 1).

The general recommended feeding rate of whole cottonseed in growing cattle is 0.33% of BW per head daily in order to limit fat and maintain adequate digestibility (Rogers et al., 2002). Cattle allowed *ad libitum* access to DP1646 consumed cottonseed at or close to the recommended rate (0.39% of BW), whereas cattle allowed *ad libitum* access to ULGCS consumed over double the recommended amount (0.78% of BW). Cattle consuming ULGCS had an average fat intake of 0.4 kg per day, whereas cattle consuming DP1646 had an average intake of 0.2 kg per day. Seed size for ULGCS was greater than DP1646, which may have increased palatability and overall daily seed intake. A study by Hill et al. (2009) evaluated mature cows consuming *ad libitum* whole cottonseed or at the recommended level of 0.5% of body weight. Cattle with *ad libitum* access consumed 4.06 kg compared to 2.41 kg for cattle consuming 0.5% of body weight. Intake for cattle with *ad libitum* access to whole cottonseed had a greater intake than the recommended amount in both the study by Hill et al. (2009) and the present study. These results indicate cattle should be limit fed whole cottonseed to avoid overconsumption and increased supplementation costs.

Gossypol Intake

Total gossypol intake was less ($P < 0.0001$) for cattle consuming ULGCS than cattle consuming DP1646. The average daily total gossypol intake for cattle consuming ULGCS was 3.1 ± 0.6 g compared with 8.2 ± 0.6 g for cattle consuming DP1646 (Figure 1).

When comparing free gossypol intake across treatment groups, free gossypol intake was less ($P < 0.0001$) for cattle consuming ULGCS than cattle consuming DP1646. The average daily free gossypol intake for cattle consuming ULGCS was 1.3 ± 0.4 g compared with 5.9 ± 0.4 g for cattle consuming DP1646 (Figure 1).

Overall, total and free gossypol concentrations for the whole cottonseed intake study were less than reported gossypol concentrations for other studies evaluating gossypol intake. Results from the present study differ from a feeding trial by Mena et al. (2004), which found that intake was greater for lactating dairy cows consuming diets high in both total and free gossypol, 1,894 mg per kg and 960 mg per kg, respectively, than a gossypol-free control diet. In the feeding trial by Mena et al. (2004), diets were fed as a TMR with whole cottonseed and cottonseed meal used to achieve the targeted gossypol levels. This delivery method might have made selectivity of whole cottonseed more difficult and eliminated potential preferential intake.

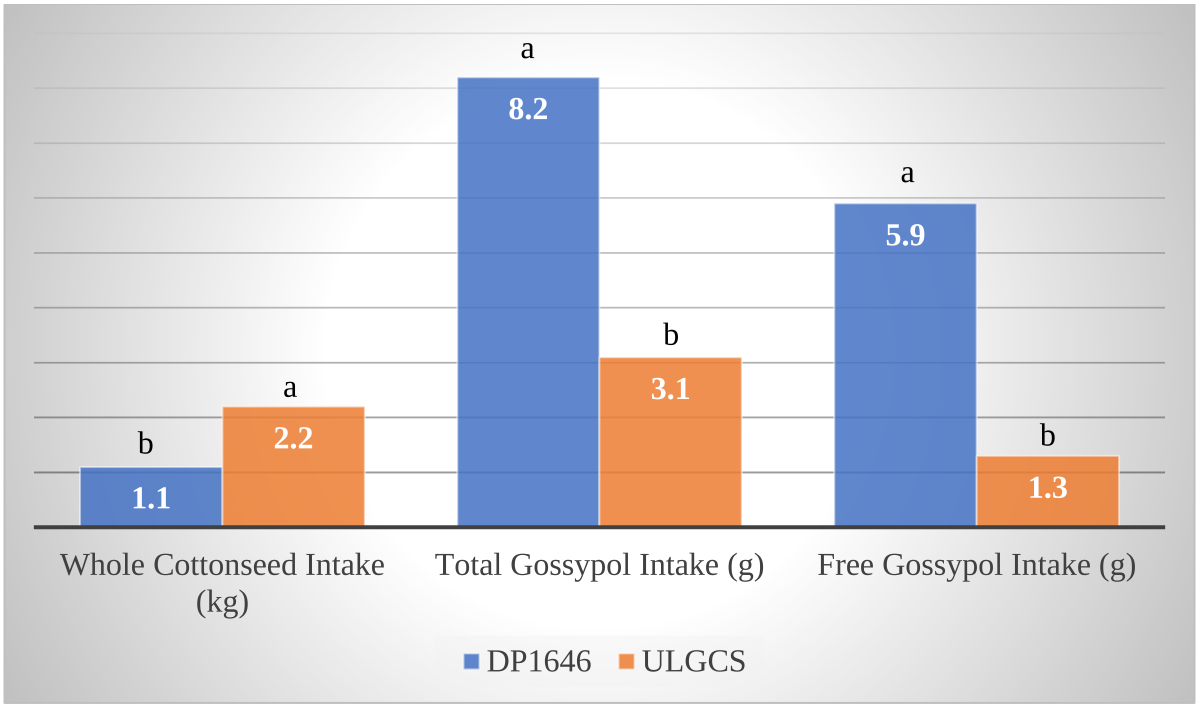

Figure 1. Average whole cottonseed intake, total gossypol intake, and free gossypol intake of Delta Pine 1646 (DP1646) and Ultra Low Gossypol Cottonseed (ULGCS); [ab]Within a category, means differ $P < 0.05$.

In situ

Cumulative whole cottonseed digestibility was 70.3% and 68.2% for ULGCS and DP1646 respectively at 48 hr of digestion (Figure 2). No treatment × time interaction was observed at 2, 4, 6, 12, 24, and 48 hours ($P \geq 0.0708$). However, at 72 hours of digestion, there was a treatment × time interaction ($P < 0.0001$).

Whole cottonseed is generally recognized as a high quality supplement for beef cattle because of the protein and energy concentration coupled with a reported TDN value of 93% (NRC, 2016). The results from this study confirm the high energy characteristics of whole cottonseed with two varieties examined being approximately 70% digestible on a DM basis. Both digestibility measurements illustrate the high nutritive potential for whole cottonseed use in beef cattle diets to meet daily energy requirements as a supplemental feed resource.

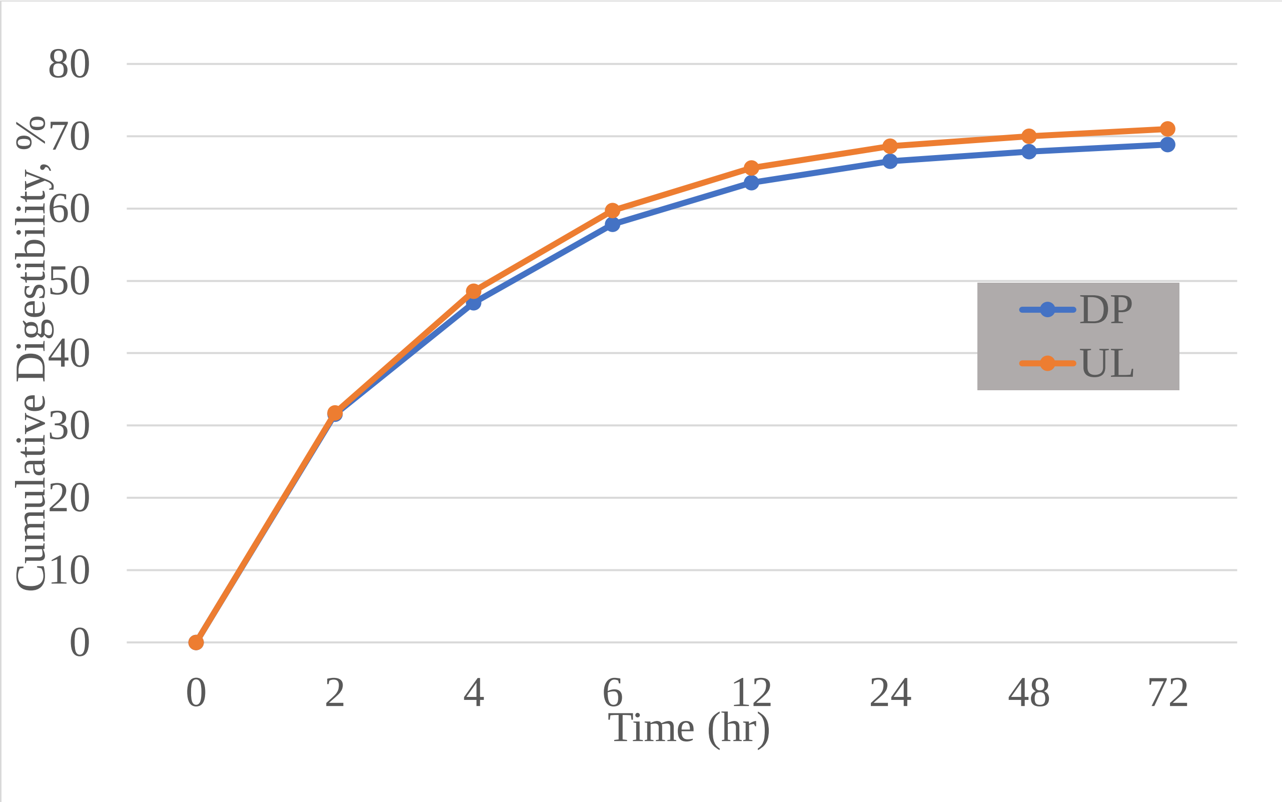

Figure 2. Cumulative digestibility (%) of Ultra Low Gossypol Cottonseed (ULGCS) and Delta Pine 1646 (DP1646) whole cottonseed at 0, 2, 4, 6, 12, 24, 48, and 72 hours.

Protein Degradability

Across the 98 cotton varieties and breeding lines obtained from the Auburn University Cotton Breeding Program, whole cottonseed had a range of 36.0% to 73.9% DIP with an average value of 52.9 ± 6.5% (Table 2). When these data are presented using a distribution at 5.0% increments, the greatest number of observations (n = 37) were between 50 and 55% DIP, with the second greatest number of observations (n = 25) between 45 and 50% DIP. There were 4 observations above 65% DIP and 6 observations below 45%. When evaluating the distribution of samples between 45 and 55% DIP, there were 62 varieties and breeding lines. Within this sample subset, 16 samples had between 47.5 and 50.0% DIP, with 25 samples having between 50.0 and

52.5% DIP, demonstrating relative consistency in terms of degradable intake protein contribution.

When evaluating concentrations of UIP across the 98 cotton varieties and breeding lines obtained from the Auburn University Cotton Breeding Program, there was a range of 26.0% to 63.9% UIP with an average value of 47.1 ± 6.5 %. In a distribution at 5.00% increments, the greatest number of observations (n = 37) were between 45 and 50% UIP, with the second greatest number of observations (n = 25) between 50 and 55% UIP. There were 6 observations above 55% UIP with 4 observations below 35%. When evaluating the distribution of samples between 45 and 55% UIP, there were 62 varieties and breeding lines. Within this sample subset, 25 samples had between 47.5 and 50.0% UIP, with 16 samples having between 50.0 and 52.5% DIP.

Little information has been reported regarding protein degradability levels in whole cottonseed. There is no reported DIP or UIP level for whole cottonseed in the Nutrient Requirements of Beef Cattle publication (NRC, 2016). However, a review by Arieli (1998) reported an average DIP of 74% for Upland cotton. The average value from lines/varieties analyzed in this study was 52.9 ± 6.5 % DIP. These differences could be caused by varying weather, stand management, genetic selection pressures, and breeding goals. Further research is also needed to establish insoluble protein fractions of UIP to more accurately determine future cotton breeding selection goals. Regardless, with the distribution of protein concentrations observed throughout the study, whole cottonseed is a viable option for supporting beef cattle performance.

Table 2. Average crude protein (CP, % DM basis), degradable intake protein (DIP, % CP), undegradable intake protein (UIP, % CP), and seed index (SI) of the cultivars/lines examined.

Cultivar/Line[+]	Observations	CP[*] (%)	DIP (%)	UIP (%)	SI
Red	3	22.2	46.6	53.4	9.8
Ark 1015-42	1	26.0	68.3	31.8	8.8
Ark 1005-41	1	24.1	52.7	47.3	10.2
Ark 1004-38	1	24.1	60.9	39.1	11.0
Ark 1005-35	1	22.5	46.6	53.4	9.6
Ark 1007-15	1	26.4	61.2	38.8	9.2
TAM LBB 150107	1	26.2	54.3	45.7	8.3
TAM LBB 150824	1	25.0	46.9	53.1	10.6
TAM LBB 15092	1	24.0	49.4	50.6	11.1
TAM 13S-03	1	22.9	49.7	50.3	9.9
TAM 12J-39	1	25.3	58.4	41.6	9.0
GA 2012141	1	24.5	50.4	49.6	10.1
GA 2015024	1	25.5	53.0	47.0	8.6
LA 14063083	1	25.4	55.1	44.9	10.0
LA 14063075	1	27.2	50.9	49.1	8.5
LA 11309040	1	24.8	47.5	52.5	7.9
PD 2011021	1	24.8	49.2	50.8	11.4
PD 2011081	1	22.2	46.3	53.7	10.2
PD 2011026	1	25.4	54.1	45.9	11.0
MS 2010-875	1	23.6	55.7	44.3	9.2
DP 393 CK	1	24.8	53.6	46.4	10.3
DP 493 CK	1	24.3	58.8	41.2	7.8
DP 1646	1	23.4	48.6	51.4	7.3
DP 393	1	23.1	50.6	49.4	10.2
FM 958 CK	1	22.9	51.5	48.5	11.1
UA 222 CK	1	23.8	60.0	40.0	10.2
UA 222	1	20.6	50.2	49.6	8.5
SG 105	1	22.3	50.4	49.6	7.7
AU 55052	1	19.8	57.7	42.3	7.7
RP 77009	1	20.8	39.4	60.5	7.4
RP 82028	1	21.6	50.36	49.7	8.2
10	1	26.8	64.4	35.6	8.7
12	12	24.1	53.0	47.0	9.5
13	1	25.4	50.0	50.0	10.9
16	1	25.0	50.7	49.3	11.7
40	2	20.4	42.8	57.2	8.4
52	2	22.0	58.6	41.4	8.7

53	2	20.5	46.9	53.1	8.8
54	2	22.9	50.5	49.5	9.2
60	1	21.3	50.1	49.9	9.9
61	1	21.9	49.8	50.2	8.1
62	2	21.4	54.7	45.3	9.3
67	1	19.7	56.0	44.0	9.8
68	1	21.6	63.1	36.9	9.4
70	4	21.5	60.5	39.5	9.0
71	1	20.5	48.9	51.1	9.2
72	2	24.7	53.2	46.8	10.0
73	1	20.5	50.6	49.4	8.7
74	2	25.0	55.1	44.9	10.8
76	4	22.1	53.7	46.3	10.1
77	2	22.2	55.0	45.0	8.3
78	1	21.3	50.3	49.7	9.4
79	3	28.9	53.2	46.8	9.5
80	5	23.0	51.8	48.2	9.9
81	5	23.6	51.7	48.3	9.8
82	2	21.9	50.5	49.5	9.7
83	3	24.7	57.3	42.7	10.1
90	1	24.8	49.9	50.1	9.6

[+]Subset of cultivars/lines, letter code indicates relation; number code indicates parent lines with first two like identifiers (‘12’).
[*]Crude Protein (CP), Degradable Intake Protein (DIP), Undegradable Intake Protein (UIP), Seed Index (SI).

Seed Index and Correlation with Protein Degradability

Seed index (weight of 100 seeds, g) was evaluated to obtain an average individual seed weight. The varieties and breeding lines evaluated in the present study had a seed index range of 7.3 to 11.7. There was little to no correlation between seed index and DIP (R = 0.0053) or UIP (R = -0.0053). The values for seed index and protein degradability are presented in Figures 3 and 4 for DIP and UIP, respectively.

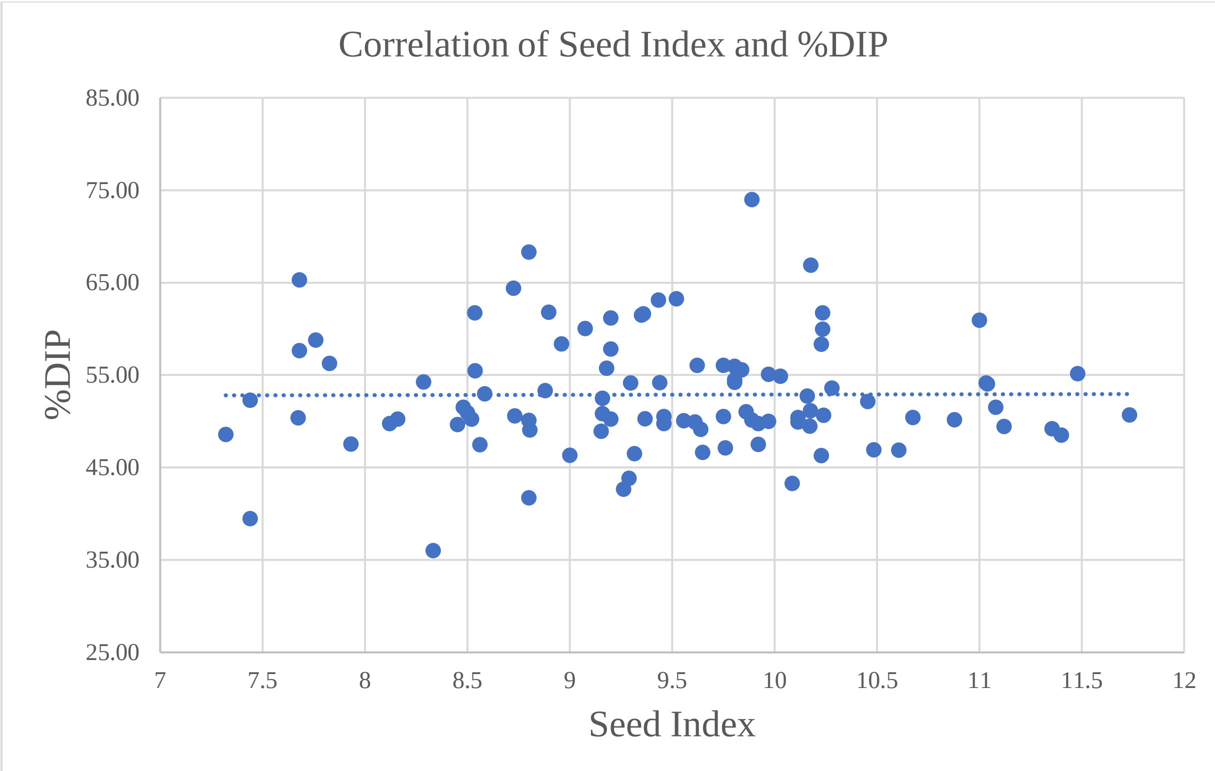

Figure 3. Correlation of seed index with degradable intake protein (DIP; % of CP).

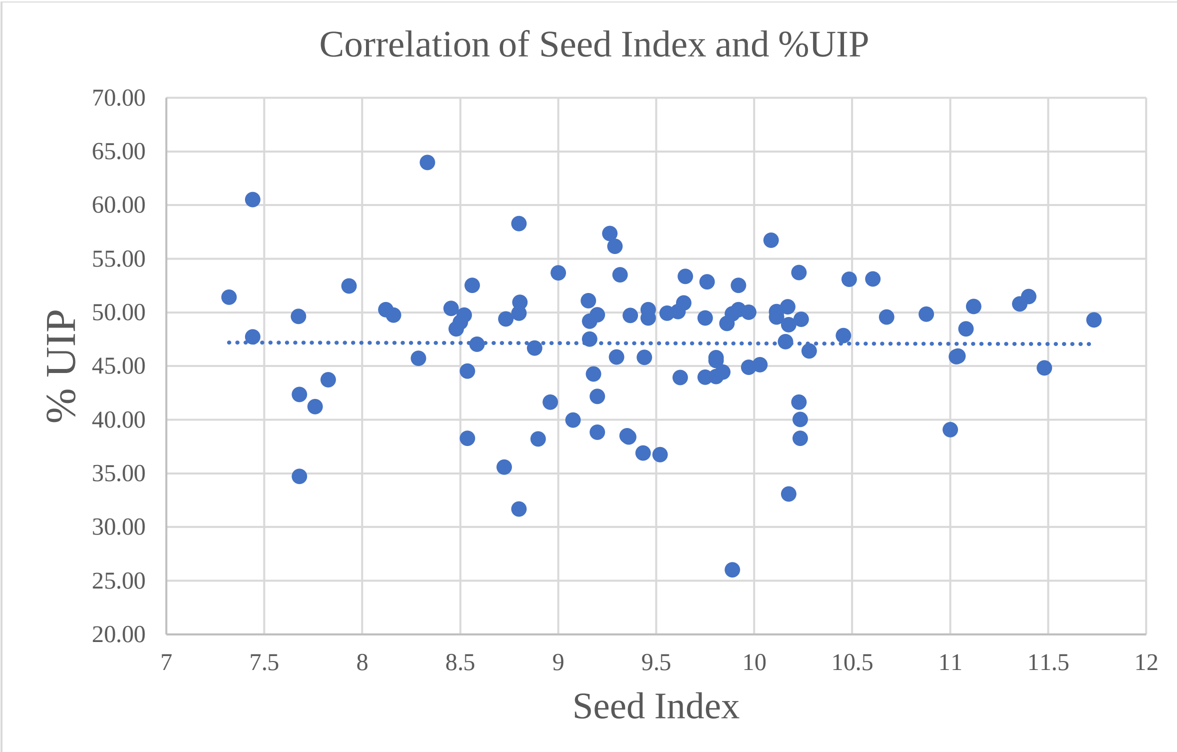

Figure 4. Correlation of seed index with undegradable intake protein (UIP; % of CP).

Summary and Conclusion

Whole cottonseed is a readily accessible byproduct feed source for beef cattle producers in the Southeast and can be easily incorporated into supplementation strategies in cotton-producing areas. Controlled feeding of whole cottonseed will help prevent overconsumption, control fat intake, and avoid unnecessary cost of supplementation. Digestibility can vary between cottonseed varieties; however, whole cottonseed is a good source of protein, energy, and digestible fiber. Nutrient use efficiency, DIP/UIP concentrations, and seed size may vary between cottonseed varieties and within loads because cotton gins are unable to separate seed in various varieties (Table 2). Results from these studies support current extension recommendations and indicate whole cottonseed can be utilized to supplement beef cattle at various stages of production.

IV. Cotton Gin Trash Assessment for Updating Beef Cattle Feeding Recommendations

Introduction

Cotton gin trash is a byproduct of the cotton industry that consists of leaves, soil, stems, boles, burs, lint, and cottonseed leftover from the ginning process (Myer, 2007). Gin trash has a low to medium feed value with a nutrient composition similar to that of low- to medium-quality hay, and it can be utilized for winter feeding programs or during times of drought or forage availability deficits (Rogers et al., 2002). Due to the low nutritive value of this byproduct, gin trash inclusion in growing cattle diets is typically limited to inclusion rates of 5 to 10 percent due to its low energy concentration. Gin trash can be included at greater amounts in non-lactating, bred cow diets due to the low nutrient requirements during this stage of production, and can be used as a substitute for low- to medium-quality hay if an energy supplement is also provided (Stewart and Rossi, 2010). Most gins store gin trash outdoors where it is exposed to weather conditions at the gin site. This exposure to weather can lead to molding, reduced palatability, and decreased nutritive value. Some gins have begun compacting gin trash into rectangular bales (0.6 m × 0.6 m × 1.8 m) with an average target weight of 227 kg, bales and binding them with plastic lashing strips to preserve the structure of the bale and ease transport, handling, and storage for beef cattle producers. Baling gin trash increases the bulk density to approximately 593 kg/m^3 compared to 160 kg/m^3 for loose gin trash. Transitioning to more bulk packaging of gin trash may add value to a traditionally limited-use cotton byproduct and increase accessibility to gin trash by more beef cattle producers.

In addition to feed quality aspects of cotton gin trash, defoliant residue threshold values have not been defined for cotton gin trash. However, a study by Stewart and Rossi (2010) showed that average residue concentrations found on cotton gin trash, 4.49 ppm, were similar to tolerance levels of whole cottonseed, 4.0 ppm, and cottonseed hulls, 6.0 ppm. Understanding the safety and efficacy of using cotton gin trash in beef cattle diets will help refine current feeding recommendations for this byproduct in beef cow-calf operations.

The objective of this study was to determine intake, animal performance, feed nutritive value, and safety of using loose or baled gin trash in beef cattle diets.

Materials and Methods

Research Site

A feed intake trial was conducted at the Auburn Bull Test and Evaluation Center, Auburn, Alabama to determine overall consumption and performance of beef cows consuming cotton gin trash. All experimental procedures were reviewed and approved by the Auburn University Institutional Animal Care and Use Committee (2020-3811).

Gin Trash Intake Trial

Sixteen crossbred, non-lactating, gestating cows (average BW, 646 kg) and 8 crossbred, gestating heifers (average BW, 516 kg) were randomly assigned to one of two groups consisting of 8 cows and 4 heifers per group. Cattle were transported to the Auburn Bull Test and Evaluation Center (Auburn, AL) and trained to the Calan Gate® system (American Calan, Northwood, NH). Cattle were allowed *ad libitum* bermudagrass-bahiagrass hay and received 2.2 kg per head per day of a 50:50 mixture of corn gluten feed and soyhull pellets (J & R Feed Services Inc, Cullman, AL; 17.5% CP, 71.3% TDN, 50.0% NDF, 28.8% ADF) in opened bunks and observed each morning to determine which bunk each cow frequented for the first 7 days. On day 8 of training, cattle were assigned a magnetic collar to open the gate that was frequented and the Calan Gate® system was activated to allow cattle to learn to open the allotted gate. On days 9 through 14 of training, cotton gin trash was added at morning feeding to acclimate cattle to the palatability and texture of the byproduct feedstuff and access to hay was restricted. Following the training and acclimation period, each group was assigned to receive *ad libitum* baled cotton gin trash or *ad libitum* loose cotton gin trash for a 60-day intake trial. Baled cotton gin trash was obtained from Henry County Gin (Headland, AL). Baled cotton gin trash is produced by compressing the loose gin trash into modules approximately 0.6 m × 0.6 m × 1.8 m and binding them with plastic lashing strips to preserve the structure of the bale to ease transport, handling, and storage (Figure 3). Loose cotton gin trash was obtained from Milstead Farm Group Inc (Shorter, AL). Loose gin trash is typically stored outdoors in piles exposed to weather (Figure 4). In addition to gin trash, all cattle received 2.2 kg per head per day of a 50:50 mixture of corn gluten feed and soyhull pellets at morning feeding to supply additional energy requirements for their respective stage of production based on the NRC (2016). Orts were weighed each morning and recorded. Body weight and body condition scores [BCS, Scale 1-9 with 1 = emaciated and 9 = obese; Wagner et al., 1988)] were recorded at days 0, 30, and 60.

Figure 3. Baled cotton gin trash from Henry County Gin, Headland, AL.

Figure 4. Loose cotton gin trash from Milstead Farm Group Inc., Shorter, AL.

Gin Trash Quality Analyses

Samples of both baled and loose cotton gin trash were collected weekly for nutritive value analyses at Auburn University Soil Testing Laboratory (Auburn, AL). Additional samples of both baled and loose cotton gin trash were collected bi-weekly for pesticide analyses and sent to Waters Agricultural Laboratories, Inc. (Camilla, GA). Mean nutritive quality and pesticide residue values for both baled and loose gin trash are presented in Table 3, values at individual weeks for gin trash are provided in the Appendix.

Table 3. Nutritive value parameters (% DM basis) and pesticide concentration of cotton gin trash used in a beef cattle intake trial.

Treatment	Dry Matter (%)	Crude Protein (%)	Total Digestible Nutrients (%)	Tribufos Concentration (ppm)
Baled Gin Trash	87.6	13.9	40.4	4.84
Loose Gin Trash	79.1	11.0	39.1	1.98

Blood Sampling

Blood parameters were collected weekly from cattle during the gin trash intake and performance trial to monitor any animal immune system responses to cotton defoliant residue, particularly organophosphates. Jugular blood samples were collected weekly using a vacutainer system consisting of a 10 mL EDTA blood collection tube (BD Vacutainer), vacutainer needle holder, and an 18 gauge, 1.5 inch vacutainer needle (VWR, Batavia, IL). blood samples were collected throughout the duration of the intake trial, and again 30- and 60-days post-study for complete blood counts (CBC with blood smear evaluation; processed by the Auburn University College of Veterinary Medicine Clinical Pathology Laboratory, Auburn, AL). Red blood cell count (RBC), hemoglobin (HGB), hematocrit (HCT), and white blood cell (WBC) are reported across treatments, days, and their interaction.

Statistical Analysis

Gin trash intake study data were analyzed using PROC MIXED of SAS 9.4 (SAS Inst., Cary, NC). Gin trash type was considered the independent variable. Gin trash intake dependent variables were individual-animal intake, BW, BCS, nutritive value, and blood parameters. Treatment means were separated using the DIFF option of the LSMEANS procedure (SAS Inst., Cary, NC) and were determined to be significant when $\alpha = 0.05$.

Results and Discussion

Gin Trash Intake

Cotton gin trash intake was greater ($P < 0.0001$) for cattle consuming than baled gin trash. The average daily intake for cattle consuming loose gin trash was 12.2 ± 0.15 kg, while average intake for cattle consuming baled gin trash was 10.9 ± 0.15 kg on an as-fed basis. Cattle assigned to the loose gin trash treatment consumed approximately 2.0% of BW compared to 1.8% of BW for cattle assigned to the baled gin trash treatment. The intake levels observed in the present study are similar to the estimated DM intake (12.8 kg or 2.0% of BW) of cattle of similar size and production stage as calculated by the Nutrient Requirements of Beef Cattle prediction equation (NRC, 2016).

There are relatively few published studies evaluating beef cattle performance using cotton gin trash. A study by Hill et al. (2000) reported an average DM intake of 12.7 kg per head for dry brood cows consuming gin trash. These findings are similar to the loose gin trash intake of the present study. In both studies, cattle provided cotton gin trash and an energy-protein supplement were able to maintain body weight and condition, illustrating the potential use of gin trash as a roughage substitute in beef cattle diets.

Body Weight and Body Condition Score

There were no treatment, day, or treatment × day interactions for beef cow BCS when consuming loose or baled gin trash ($P \geq 0.6962$). Both treatments, loose and baled, were able to maintain cow BW and condition throughout the duration of the study. All cattle maintained BW appropriately for the stage of production during the trial (Table 4).

There were no day or treatment × day interactions for BCS ($P \geq 0.0884$); however, cattle consuming baled gin trash had a greater BCS ($P = 0.0173$) than cattle consuming loose gin trash (Table 5). When considering the difference in BCS between baled and loose gin trash, a biologically relevant difference was not observed, and cattle maintained a desirable and recommended level of BCS prior to entering the calving period.

Similar to a study reported by Stewart and Rossi (2010), cattle were able to maintain BW consuming gin trash when additional energy supplementation was provided. In addition, Rogers et al. (2002) conducted a two-year study to evaluate beef cattle performance with access to limit grazed gin trash modules. Cattle in the first year gained weight, but lost BCS, whereas cattle in the second year received additional energy supplementation from whole cottonseed and gained both BW and body condition (Rogers et al., 2002).

Table 4. Cow body weight change during cotton gin trash feeding trial.

Treatment	Day 0	Day 30	Day 60	Mean
-	-------------------	-------kg-------	-------------------	
Baled†	603	618	621	614
Loose	602	613	623	613
Mean	603	615	622	-
SE	23	23	23	13

†Treatments included daily hand feeding of compressed bales or loose gin trash to beef cattle.

Table 5. Cow body condition score during cotton gin trash feeding trial.

Treatment	Day 0	Day 30	Day 60	Mean
Baled	6.5	6.6	6.3	6.5[a]
Loose	6.1	6.3	6.0	6.1[b]
Mean	6.3	6.5	6.1	-
SE	0.2	0.2	0.2	0.1

[a,b] Within column, means differ ($P < 0.05$).

Complete Blood Counts

Red blood cell counts (RBC) reflect the total number red blood cells within a given sample. In general, beef cattle have greater RBC counts than dairy cattle, and dry cows have greater RBC counts than lactating cows (Roland et al., 2014). Changes in RBC may be indicators of anemia, which can potentially occur due to prolonged exposure to a toxicity. In this case, there are no published data related to gin trash feeding safety, and blood parameters were collected to help quantify if possible defoliant residues could impact animal health during and after feeding. There were no treatment differences or treatment × day interactions for RBC ($P \geq 0.7694$); however, a difference ($P < 0.0001$) was observed for day.

Hemoglobin (HGB) is the oxygen-transporting protein in red blood cells and reflects the amount of red blood cells present in the blood. Both treatment and day were different ($P \leq 0.0371$) for HGB, but no treatment × day interaction was observed ($P = 0.9062$).

Hematocrit (HCT) is the volume percentage of red blood cells in the blood, which can reflect the amount of red blood cells present in the blood. There were no treatment differences or treatment × day interactions for HCT ($P \geq 0.1149$); however, a difference ($P < 0.0001$) was observed for day.

White blood cells (WBC) are essential for immune system function, and their relative count may provide an indicator of relative stress response to toxicity exposure in livestock. There were no treatment differences or treatment × day interactions for WBC ($P \geq 0.3450$); however, a difference ($P < 0.0406$) was observed for day.

Throughout the duration of the study, cattle showed no visible signs of stress or reduced feed intake, which further supports blood parameter observations that cattle were not experiencing negative health impacts from the short-term feeding of cotton gin trash in this study. Average reported values across all blood parameters examined were within the acceptable ranges provided by the Auburn University College of Veterinary Medicine Clinical Pathology Laboratory (Table 6).

Table 6. Complete blood count results from cotton gin trash intake trial.

Treatment	Red Blood Cell Count	Hemoglobin (g/dL)	Hematocrit (%)	White Blood Cell Count
Baled†	7.1	11.9	33.3	8.3
Loose	7.1	12.2	33.9	8.0
Mean	7.1	12.1	33.6	8.1
SE	0.1	0.1	0.3	0.2
Acceptable Range*	5.0 – 10.0	8.0 – 15.0	24.0 – 46.0	5.0 – 10.0

†Treatments included daily hand feeding of compressed bales or loose gin trash to beef cattle.
*Reference ranges defined through assays and database generation through the Auburn University College of Veterinary Medicine Clinical Pathology Laboratory (Auburn, AL).

Summary and Conclusion

Gin trash is readily available to beef producers in cotton producing areas and can be incorporated into winter feeding strategies or utilized to replace low- to medium-quality hay. Due to the low bulk density, transportation of loose gin trash long distances is not feasible; therefore, baled gin trash may be a better option to widen the scope and reach of this byproduct to end users. Baled gin trash also allows easier handling and storage which could allow quality to be maintained throughout the duration of feeding. Both loose and baled gin trash can be used to maintain non-lactating, bred cows with little additional energy supplementation, and provide an outlet for cotton byproduct waste to be used in beef cow-calf operations in the Southeast US.

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Appendix

Appendix Table 1. Cotton Varieties and Lines Tested for Protein Degradability Fractions

Groups Identifiers†	Individual Cultivars/Lines					
Red	Red Advanced PBU	Red Weaver Wire	Red Elite Brewton			
Ark	Ark 1015-42	Ark 1005-41	ARK 1004-38	Ark 1005-35	Ark 1007-15	
TAM	TAM LBB 150107	TAM LBB 150824	TAM LBB 15092	TAM 13S-03	TAM 12J-39	
GA	GA 2012141	GA 2015024				
LA	LA 14063083	LA 14063075	LA 11309040			
PD	PD 2011021	PD 2011081	PD 2001026			
MS	MS 2010-875					
DP	DP 393 CK	DP 493 CK	DP 1646	DP 393		
FM	FM 958 CK					
UA	UA 222 CK	UA 222				
SG	SG 105					
AU	AU 55052					
RP	RP 77009	RP 82028				
10	10090					
12	128092	122048	122072	122045	124016	127098 PB
	128071	123037	128089	121036	126069	122034
13	134079					
16	16-13P1115					
40	4051	4079				
52	52021 PBU	52079 PRATT				
53	5315	5346				
54	5418	5428				
60	6001					
61	6126					

62	6252	6202				
67	67059					
68	68088					
70	70049	70001	70062	70049		
71	71069					
72	72021	72028				
73	73055					
74	74044	74088				
76	76074	76008	76038	76036		
77	77009	77053				
78	78080					
79	79056	79085	79094			
80	80030	80065	80098	80003	80006	
81	81019	81043	81071	81097	81025	
82	82028	82074				
83	83046	83100	83060			
90	90098					

†Within a row, varieties/lines from the same program or parentage evaluated are listed.

Appendix Table 2. Gin trash defoliant and nutrient (% DM Basis) concentration per week.

	Tribufos Concentration (ppm)		Crude Protein (%)		TDN (%)	
Week+	Baled*	Loose	Baled	Loose	Baled	Loose
1.	6.9	0.6	13.4	7.12	47.1	46.7
2.	9.5	3.5	12.4	11.5	39.1	40.3
3.	-	-	14.2	10.9	40.4	40.7
4.	4.2	3.0	12.8	11.7	41.2	38.6
5.	-	-	16.0	11.3	41.7	37.5
6.	2.1	0.8	12.8	11.4	40.5	37.0
7.	-	-	14.6	10.1	39.7	37.3
8.	1.4	1.9	15.2	13.8	38.3	39.2
Average	4.8	1.9	13.9	11.0	40.4	39.0

+ Residue samples taken bi-weekly after initial report; weeks represent 0-60 d of feeding.
* Baled or loose cotton gin trash.