

ABSTRACT

MULLINS, ELIZABETH PEYTON. Utilization of Cotton Ginning Byproduct and Whole Cottonseed as a Feed Source in Growing Cattle. (Under the direction of M.H. Poore).

Cotton production and processing results in several byproducts. Two of these byproducts are whole cottonseed and cotton gin byproduct (also referred to as cotton gin trash). Whole cottonseed is more marketable than cotton gin byproduct and thus receives more attention concerning research and market reporting. However, there is little information regarding the local supply chain and utilization of these byproducts. A study was conducted to determine how whole cottonseed and cotton gin byproduct are marketed in North Carolina. A 19-question survey was developed and disseminated to all 34 cotton gins in the state resulting in a 73.4% response rate (n=25). All respondents reported that the majority of their whole cottonseed was marketed out-of-state as livestock feed. In contrast, 78% of respondents reported that the majority of their gin byproduct was utilized in-state. It was found that 40% of cotton gin byproduct is being utilized as cattle feed and the remaining 60% is either being stockpiled and allowed to decompose on-site or used as compost. Of the respondents, 95% already sell gin byproduct locally as cattle feed or would consider doing so. The majority of respondents (92%) agreed to be added to a directory to be distributed to cattle producers. A second study was established at the NCSU Butner Beef Cattle Field Laboratory (Bahama, NC) to evaluate the use of whole cottonseed and cotton gin byproduct as cattle feed in the diets of growing steers. This study utilized a randomized block experimental design. Steers were blocked by bodyweight (BW) and placed into groups of 8 in 7 pens equipped with Calan gate electronic feeders (American Calan, Northwood, NH). Treatments were randomly assigned to steers within each pen. The four treatments were: a corn silage-based ration supplemented with ground corn and soybean meal (TRT 1), a corn silage-based ration with whole cottonseed (TRT 2) occupying

15% of the diet on a dry matter basis, a corn silage-based ration with cotton gin byproduct (TRT 3) comprising 25% of the diet on a dry matter basis, and a corn silage-based ration with both WCS and CGB occupying 15% and 20% of the diet respectively on a dry matter basis (TRT 4). All diets were formulated to have approximately 73% total digestible nutrients (TDN) and 14% crude protein (CP). There were 14 steers assigned to each treatment with treatments replicated within each pen. Angus steers (n=56; initial BW=288 ± 3.8 kgs.) were individually fed diets for 84 d. Blood serum samples were collected on d 0, d 28, d 56, and day 84 and Blood Urea Nitrogen analysis performed. Feed intake and steer performance data were analyzed using the PROC GLM procedure of SAS and BUN data were analyzed using a PROC GLM repeated measures analysis in SAS (SAS Institute Inc. Cary, NC). Total dry matter intake (DMI) by treatment were 8.9, 8.5, 11.3, and 10.2 kg /d (P<0.0001; SE=0.78), respectively. Steer average daily gain (ADG) by treatment were 1.3, 1.2, 1.5, and 1.3 kg. (P<0.0001; SE=0.12). Feed conversion ratios for treatments were 6.8, 6.8, 8.7, and 8.2. (P<0.0001; SE=0.52). The BUN values per diet were 3.44, 4.18, 4.09, and 3.89 mM (P<0.0001; SE=0.14). BUN values increased over the 84-d trial period (P<0.0001; SE=0.14). This research established that cotton byproducts are available for use as cattle feed in North Carolina and can be purchased from most cotton gins in the state. The inclusion of WCS and CGB independently or in combination adequately supported steer growth in a confinement stocker steer situation. Cotton gin byproduct may become a readily used cattle feed; however, DMI and feed cost should be considered when incorporating these byproducts.

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Utilization of Cotton Ginning Byproduct and Whole Cottonseed as a Feed Source in Growing Cattle

by
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DEDICATION

To my grandparents Donnie and Patsy Mullins, and Burns and Patricia McFall. I owe much of my success to your love, hard work, and tenacity. Thank you for your encouragement, support, and prayers. Happy 60th Wedding Anniversary!

BIOGRAPHY

Elizabeth Peyton Mullins was raised in the mountains of Clintwood, Virginia. Elizabeth's interest in agriculture was developed early on. She has always had a keen interest in growing plants and rearing animals. Time spent gardening with her grandparents and on her family's small farm only intensified this passion. Throughout middle school and high school Elizabeth was actively involved in 4-H and FFA. She graduated salutatorian from Ridgeview High School in 2016. Elizabeth attended Virginia Tech from 2016-2019 where she obtained her Bachelor of Science in Animal and Poultry Sciences with a minor in Agribusiness Management. It was here that Elizabeth became interested in ruminant nutrition and forages. Following her graduation from Virginia Tech, she began her pursuit of a Master of Science degree in Animal Science at North Carolina State. Following the completion of her degree, Elizabeth will begin her career with Virginia Cooperative Extension in Page County, VA as an Agriculture and Natural Resources Associate Extension Agent.

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CHAPTER 1: LITERATURE REVIEW

Beef Cattle Production in North Carolina

The beef cattle industry is an important sector of agriculture in both the United States and North Carolina. In the United States there are over 93.6 million head of cattle and calves that are responsible for over \$77,000,000,000 in sales (NASS, 2017). In 2019, cattle and calves were responsible for 2.1% (\$219,234,000) of all farm cash receipts in North Carolina (NASS, 2020b). Unlike many other commodities, the North Carolina beef cattle industry is prominent throughout all three of the geographic regions of the state (NASS, 2020b). In January of 2020, it was estimated that there were 810,000 head of cattle in North Carolina including dairy and beef heifers, steers, cows, and bulls for a total value of \$599,400,000 (NASS, 2020b).

For decades, stockering calves has been an economically viable enterprise across the Southeast (Rankins and Prevatt, 2013). The stocker cattle industry is based on adding body weight by utilizing forages or byproducts at a lower cost than could be done in a feedlot (Rhinehart and Poore, 2013). A “stocker” generally refers to a weaned calf that is grown predominantly on standing forage and may be provided with supplementation (Johnson et al., 2010). A “backgrounding” operation refers to growing weaned calves with a high concentrate ration, likely in drylot housing (Rhinehart and Poore, 2013). In either of these systems, profitability can only occur when the value of body weight gain exceeds the cost of body weight gain (Rankins and Prevatt, 2013).

Changes in feed, fuel, and fertilizer prices during the previous two decades have increased the amount of capital needed to purchase growing cattle and to provide the feed necessary for body weight gain (Ranking and Prevatt, 2013). One way to improve profitability is

through the reduction of production costs. One of the greatest production costs incurred by a beef cattle operation is feed cost (Ahola and Hill, 2012). Rogers and Poore (1995) list three ways in which production costs may be reduced: 1) lessen supplemental feed cost 2) optimize pasture use or 3) match cattle genetics to the production environment. Rankin and Prevatt (2013) found the system most likely to yield inexpensive body weight gains was one that uses quality cool-season forages with co-product or byproduct supplementation.

Byproduct Feeds

The food and fiber industries produce numerous waste products. Solid waste disposal at a landfill is expensive and incineration is no longer a viable disposal method for most industries since the 1970 Federal Clean Air Act (Thomasson, 1990). Increased livestock feed costs create a need for low-cost, alternative feeds. This has increased the use of byproduct feeds. Byproduct feeds are waste products that have nutritional value and can be used as alternative sources of energy, protein, or roughage in livestock diets (Rogers and Poore 1994). Since these products are often considered “waste” by the manufacturer, they are often sold at a low cost (Schingoethe, 1991). Byproduct feeds can be more readily utilized by ruminants due to the rumen’s ability to effectively process “waste” products into usable substrates (Chase, 1982).

Some consideration must be given when choosing to utilize byproduct feeds. Although often cheaper than traditional feedstuffs, byproduct pricing may be volatile. Other considerations include nutrient composition, moisture content, availability, transportation, storage, contaminants, and feed regulations (Rankins, 2002). The nutrient composition of many byproduct feeds can be extremely variable (Schingoethe, 1991). Because of this, producers should always obtain a nutrient analysis on all byproduct feeds when formulating diets and when

obtaining a new load of byproducts. The nutrient analysis should contain data for moisture content, crude protein (CP), energy, fiber, minerals, and any pertinent information specific to the byproduct being analyzed (Schingoethe, 1991). Byproduct feed availability may be limited to a specific geographic location or season. Some byproducts may be purchased at a lower price during a specific season. For example, whole cottonseed prices are usually lowest during the ginning season (Rogers and Poore, 1994). Many byproducts have low bulk density, making transportation and storage more difficult. Additionally, some byproducts require special storage considerations such as an open commodity shed as they do not flow well through traditional bins or auger systems (Rogers and Poore, 1994). Byproducts are often considered waste products by the industries that produce them. This can make them more susceptible to contamination. Potential contaminants include mycotoxins (such as aflatoxin), weed seeds, chemical residues, and trash (Rankins, 2002). The American Association of Feed Control Officials or AAFCO have established definitions for acceptable byproducts (Rogers and Poore, 1994). Nontraditional feeds that are not recognized by AAFCO may be fed, but consideration should be given to the potential for contamination and liability (Rogers and Poore, 1994).

Cotton History

Cotton is often esteemed as the world's most important textile crop (Brubaker et al, 1999). Cotton is a dual-use crop that provides both lint, used for textiles; and oilseed, used for nutritional products for humans and livestock. The origins of cotton are not definite, but as early as 200 BC it was being used for textiles in India (May and Lege, 1999). Alexander the Great was responsible for bringing cotton cloth to Europe and by the early 1600s cotton textile mills were established in Great Britain (May and Lege, 1999). While there was use of cotton among the

Native Americans, the beginning of the cotton industry in North America commenced when the colonists arrived in Jamestown, Virginia in 1607 (May and Lege, 1999).

Cotton Production

Cotton production and consumption varies globally but the long-term trend is upward. Cotton supply and demand are driven by biotech innovations, farm mechanization, population growth, and economic growth (Cotton Sector at a Glance, 2020). India and China are responsible for approximately half of the global cotton production (Cotton Sector at a Glance, 2020). The United States is the world's leading cotton exporter, providing approximately 35% of global cotton exports (NASS, 2017).

During the 2019 marketing year, that goes from August 2019-July 2020, the United States produced almost 20 million bales of cotton, worth \$7 billion in total value (lint plus seed) (Cotton Sector at a Glance, 2020). Cotton is grown in 17 states across the United States. These states are often referred to as the "Cotton Belt" and stretch from Virginia to California (Cotton Sector at a Glance, 2020). In the United States cotton is planted from March to June and harvested from August to December (Cotton Sector at a Glance, 2020). Texas is the largest cotton producer, producing almost 40% of the cotton produced in the United States (Cotton Sector at a Glance, 2020).

The two primary species of cotton cultivated for commercial use are Upland cotton (*Gossypium hirsutum*) and Pima cotton (*Gossypium barbadense*). Upland cotton makes up the majority of United States production at 97% with Pima cotton making up only 3% (Cotton Sector at a Glance, 2020). Upland cotton is characterized by its short fiber length of 1 to 1 ¼ inches, while Pima is 1 3/8 inches or longer (Cotton Sector at a Glance, 2020). Upland cotton is

commonly used for apparel, curtains, upholstery, hospital, and medical use. Pima cotton is used in expensive/high-end apparel and for sewing thread (Cotton Sector at a Glance, 2020). Upland cotton is the species commonly grown in the Southeast and is what is grown in North Carolina (NASS, 2020b).

North Carolina ranked 5th nationally in Upland cotton production in 2020, producing 5.4% of the United States' Upland cotton (NASS, 2020b). Over 95% of Upland cotton varieties planted in North Carolina are biotech varieties (NASS, 2020b). Cotton production was responsible for 2.9% of farm cash receipts (\$309,947,128) in North Carolina in 2019 (NASS, 2020b). Most of the cotton in North Carolina is produced in the Coastal Plain region (NASS, 2020b). Planting dates in North Carolina begin mid-April, are most active May 1st-20th, and end in early June (NASS, 2020b). Harvesting in the state begins at the end of September, is most active between October 10th and November 15th, and ends in early December (NASS, 2020b). In 2019 there were 510,000 acres of upland cotton planted and 500,000 acres harvested with a yield of 453 kg. per acre (NASS, 2020b) Approximately, 1,040,000 bales (218 kg. bales) were produced for a value of \$303,245,000 (NASS, 2020b).

Cotton Harvesting

Cotton is mechanically harvested in one of two ways in the United States, either by a spindle picker or cotton stripper (Williford et. al, 1994). The spindle picker is very selective and only removes cotton from well-opened bolls, while the cotton stripper is non-selective and removes well-opened bolls along with cracked and unopened bolls, burrs, leaves, and stems (Williford et. al, 1994). The spindle picker is the most common method of harvesting; however,

the cotton stripper is the main harvester used in southern Kansas, western Oklahoma, and the high and southern rolling plains of Texas (Wanjura et al., 2010).

Cotton strippers have very high harvesting efficiency at 98-99% but at the expense of large amounts of foreign material such as burrs, stick and fine trash (Williford et. al, 1994). Fine trash is made up of fine leaf trash and soil. Some stripper harvesters make use of field cleaners or extractors that are capable of removing 60-70% of foreign matter and can reduce the amount of trash handled by the gin (Williford et. al 1994). For each 218-kg. bale of cotton lint produced from stripper harvested seed cotton there is 318-454 kgs. of trash generated (Parnell et al., 1994). Spindle pickers are used in North Carolina and across the Southeastern United States. Spindle pickers can operate up to 95% efficiency but often only operate at 85-90% efficiency (Williford et. al, 1994). For each 218 kg. bale of cotton lint generated from spindle harvested seed cotton there is 34-68 kgs. of trash material generated (Parnell et al., 1994).

Cotton Ginning

Cotton ginning “encompasses both the final stage of agricultural production and the initial stage of the manufacturing process” (Aiken, 1973). Initially, cotton gin referred only to the machine that separated lint from seed, now known as a gin stand. Today, cotton gin refers to the entire integrated ginning plant where seed cotton is dried and cleaned, lint is separated from seed, and fiber is baled. Eli Whitney patented the cotton gin and revolutionized the cotton industry by speeding up the ginning process (Aiken, 1973). Before the Civil War, cotton ginning was not the industry it is today, as most cotton was ginned on the farm or plantation rather than at a public ginners (Aiken, 1973). After the Civil War public ginners became widely accepted. During this time Robert S. Munger developed a “ginning system” where cotton was moved by

air, gravity, and belts. A pneumatic system removed seed cotton from wagons and transported it to a “separator” which removed some of the trash. A belt took the seed cotton from the separator and delivered it to the gin stand feeders. The lint left the gin stand and traveled on a conveyor to the press box. This was the beginning of the modern cotton gin. Cotton ginning technology has changed dramatically since this time, but current cotton gins still use this basic flow of cotton through the gin that Munger developed (Aiken, 1973; Hughs, 2016).

Once at the gin, seed cotton is dried and sent through a series of cleaners and extractors. The cleaning and extracting system serve a few critical purposes, removing burs, limbs, and branches so that the gin stand can operate at peak efficiency and to avoid equipment wear and malfunction as well as to obtain optimum cotton grades and market value (Baker et. al, 1994). The amount of cleaning and extracting required depends on whether the cotton was harvested with a spindle picker or cotton stripper (Baker et. al, 1994). After cleaning and extracting, seed cotton goes to the gin stand where the seed is plucked from the fiber. Following the gin stand, the lint is pressed into 218 kg. bales. For the 2020 North Carolina crop 541,800 bales of cotton were ginned, which was down from the 2019 crop of 1,061,150 bales ginned (NASS- Cotton Ginnings, 2020). The decline in cotton bales ginned in 2020 was a result of pricing favoring alternative crops such as corn and soybeans, as well as severe weather events that occurred across the United States (USDA, 2021).

Cotton Byproducts

The cotton industry generates a variety of byproducts. Cotton ginning creates gin trash, motes, and whole cottonseed. Cottonseed processing produces cottonseed meal and cottonseed hulls. Cottonseed hulls and gin trash are roughage sources and cottonseed products are a protein,

energy, and phosphorus source (Blasi and Drouillard, 2002). Per metric ton of cottonseed crushed there is 270 kg. of hull (27%), 450 kgs. of meal (45%), 80 kgs. of linters (8%), 40 kgs. of waste (4%), and 160 kgs. (16%) of crude oil (National Cottonseed Products Association, 2000).

Cotton Gin Byproduct

Cotton gin byproduct is composed of fragments of leaves, stems, bolls, cottonseed, and soil (Rogers and Poore, 1994). Cotton ginning byproduct is also commonly called cotton gin trash, gin trash, cotton burrs, or cotton ginning waste. Holt et al. (2003) suggested that terminology was a primary obstacle to the adoption of utilizing cotton gin trash. Henceforth, cotton gin trash will be referred to as cotton gin byproduct. Cotton gin byproduct may contain up to 22% permanganate lignin, causing it to decompose very slowly (Conner and Richardson, 1987). This is an issue for cotton gins because gin byproduct occupies space, is a potential fire hazard, and may lead to water contamination (Mayfield, 1991; Thomasson et al. 1998). Cotton gin byproduct can be disposed of in solid waste disposal landfills but tipping fees have increased and this is likely no longer an economically viable option (Thomasson, 1990). Parnell et al. (1994) estimated that the ginning industry spent between \$15-25 million on gin byproduct disposal. Approximately 37% of U.S. cotton gins dispose of gin byproduct at a profit or at no cost, while 63% pay for disposal (Buser, 2001). Common disposal methods for cotton gin byproduct are composting, cattle feed, and direct application of raw cotton gin byproduct to the land. (Parnell et. al, 1994). A 1997 Texas High Plains survey showed that 48% of gin byproduct was fed to livestock, 33% applied to fields, and 16% composted (Castleberry and Elam, 1998). Utilizing cotton gin byproduct as livestock feed is not a new concept.

The most common method is direct application to land using spreader trucks (Parnell et al., 1994). Cotton gin byproduct applied to soil can improve water holding capacity, reduce surface crusting, improve tilth, provide organic matter, and reduce soil erosion (Huitink, 2002). Cotton gin byproduct nutrients vary, but on average per ton of dry weight there is 25 lbs. of nitrogen, 12 lbs. of phosphorus, and 25 lbs. of potassium (Anthony et al., 1994). Weed seed contamination of cotton ginning byproduct is common (Norsworthy et al., 2009). A germination trial conducted by Norsworthy et al. (2009) found that there were 25 weed species in the cotton gin byproduct samples they analyzed from Arkansas, western Tennessee, and Mississippi. Palmer amaranth (*Amaranthus palmeri*) was the most prominent broadleaf weed (Norsworthy et al., 2009). Dispersal by cattle could prove to be an issue, especially with herbicide resistant weeds, such as Palmer amaranth. Seed viability of redroot pigweed (*Amaranthus retroflexus*) was only reduced by 52% during rumen digestion (Blackshaw and Rode, 1991). Composting cotton gin byproduct offers the additional benefits of destroying weed seeds, pathogens, common fungal disease organisms, and a 40% reduction in volume (Griffis and Mote, 1978; Baker et al., 1994).

Cotton gin byproduct is 7% crude protein (CP) and 44% total digestible nutrients (TDN) on a dry matter basis (NRC, 2000). However, it can be highly variable in nutrient composition depending on the region of production (Myer, 2007). A summary analysis of cotton gin byproduct from 26 gins in Georgia was conducted during the harvest season of 1997 and found moisture to range from 8.3% to 60%, CP 7.4% to 15.8%, TDN from 11.4% to 62.2%, and ash from 4 to 20.6% (Stewart et al., 1998). Cotton gin byproduct is a source of physically effective fiber and has the ability for use as an economical roughage. On an energy basis, roughage is one of the most expensive feed ingredients (Galvayan and Duff, 2002).

Digestibility of gin byproduct is typically low in ruminants compared to other roughages (Thomasson et. al, 1998). Plant components consist of cellulose, hemicellulose, lignin, and minerals. It is well documented that the relative proportions of these components change with respect to both plant part and stage of maturity. Maturation alters the plant making it less digestible. With cotton gin byproduct, the plant parts are at the maximum stage of maturity and are mostly stem and with little leaf material (Conner and Richardson, 1987). Additionally, minerals depress the digestibility of cellulose; consequently, cotton gin byproduct with high ash content may hinder digestibility and performance (Conner and Richardson, 1987).

When purchasing cotton gin byproduct, it is important to know if the product has been sprayed down with water as this could cause mold and rot, ultimately reducing feeding value. In order to remain in compliance with fugitive dust regulations, gins that use cyclones to drop gin byproduct in a pile will often add nozzle spray systems to wet down the byproduct with water to reduce dust (Baker et. al, 1994).

Using cotton gin byproduct in livestock rations has the potential to increase gin profits, reduce landfill disposal, and add an alternate roughage feed for the livestock industry. Aside from the cost of hauling and transportation, cotton gin byproduct is often at no cost to purchase (Myer, 2007). Erwin and Roubicek (1958) found gin byproduct to be as palatable as silage and that molasses did not further improve palatability, rate of gain, or feed efficiency. They found that when fed as part of the roughage portion rather than the sole roughage source, steer gains were equal to steers fed silage as their roughage source (Erwin and Roubicek, 1958). Holloway et al. (1974) found that steers fed gin byproduct as their major energy source gained slower, had lighter carcasses, and reduced back fat compared to steers that received a sorghum silage-based diet or sorghum silage and gin byproduct diet. They also found that there were no differences in

rate of gain or carcass characteristics between the steers fed sorghum silage and no gin byproduct and the steers that received sorghum silage and gin byproduct. Sagebiel and Cisse (1984) confirmed that gin byproduct fed alone results in diminished performance with their study utilizing pregnant cows. They reported loss of weight in pregnant cows when fed gin byproduct alone, but the addition of cottonseed improved gains. Kennedy and Rankins (2008) found cotton gin byproduct to be a better low-cost roughage source than peanut hulls.

A 1999 statistical model used to develop the demand relationship for cotton gin waste as a roughage ingredient in cattle feedlot rations found that feeding returns almost double when cotton gin waste was included at 10% of the ration on a dry matter basis due to a reduction in feed costs (Castleberry and Elam, 1999). They concluded that if feedlots were not using cotton gin waste their returns were not being maximized. Castleberry and Elam (1999) noted that there should be more interest from a nutritional perspective and more feedlots should be feeding it. They also suggested that it should be given a new name.

A study conducted by Oklahoma State found that steers fed a “Cotton Byproduct Diet” (cotton ginning byproduct, cottonseed, and rolled corn) compared to a “Control Diet” (prairie hay, sweet bran, rolled corn, and corn steep) had heavier gains, greater ADG, higher dry matter intake, heavier final body weights, higher dressing percentages and no differences in gain to feed ratios or carcass qualities (Warner et al., 2020). The study concluded that cotton byproducts can be used as protein, fat, and fiber sources in feedlot rations without adverse effects on performance or carcass characteristics (Warner et al., 2020).

Physical Processing of Cotton Gin Byproduct

Cotton gin byproduct can undergo physical processing to improve feeding value and handling. Cotton gin byproduct has a low bulk density that can make it difficult to haul and transport, this can be improved by putting gin byproduct into bales, cubes, or modules (Rogers and Poore, 1995). Arndt et al. (1980) found that when cotton gin byproduct was pelleted there were reductions in feed efficiency possibly due to particle size reduction increasing rumen passage rate, therefore, decreasing fermentation time. Cleaning is another way to physically process cotton gin byproduct. Cleaning is accomplished by screening the gin byproduct to remove fine particles, such as soil (Axe et. al, 1982). In this study the ginning byproduct was screened with a 20-mesh screen. A U.S. Standard 20-mesh screen is a screen that has 20 openings in 6.5 cm², these openings are 850 microns in diameter. Then a feeding trial was conducted to compare the cleaned gin byproduct to the uncleaned. The cleaned gin byproduct had a 25% reduction in ash content, improved rate of gain, increased feed intake, and improved feed conversion (Axe et. al, 1982). Removing soil contamination from plant material reduces the free ash content, improving fiber digestion and thus the quality for feeding livestock (Holt et. al, 2003).

Chemical Processing of Cotton Gin Byproduct

Cotton ginning byproduct can be chemically treated to improve its feeding value. Ozonation and treatment with sodium hydroxide have been proven to increase digestibility (Rogers and Poore, 1995). A Texas Tech study found that chemically treating cotton gin byproduct with 4% sodium hydroxide or nitric and sulfuric acid both increased apparent dry matter digestibility and organic matter digestibility (Arndt et al., 1980). As plants mature,

lignification of structural carbohydrates occurs (Conner and Richardson, 1987). The aforementioned chemical treatments help to make these carbohydrates available to rumen microbes by breaking lignified matrices (Arndt et al., 1980). The most common chemical treatment is sodium hydroxide, which works to solubilize hemicellulose without disturbing cellulose content (Conner and Richardson, 1987; Klopfenstein, 1978). Sodium hydroxide is most commonly applied as a 25% sodium hydroxide solution at a rate of 7.3 kg/100 kgs. of dry matter (Conner and Richardson, 1987). Feeding cotton ginning byproduct treated with sodium hydroxide may cause a sodium overload in the animal (Arndt et al., 1980). Optimum digestibility occurred when only 40 to 50% of the diet was treated with sodium hydroxide (Arndt et al., 1980) While chemical processing improves digestibility, it is not commercially utilized. This is likely due to the added cost of further processing

Whole Cottonseed

Approximately 60% of cottonseed in the United States goes to oil, meal, and hulls while 38% is used as livestock feed, and the remaining 2% used for planting. (Willcutt & Mayfield, 1994). A 2016 Cotton Inc. publication estimates that approximately 50% of whole cottonseed is sold specifically for livestock consumption (Wedegaertner, 2016). Cottonseed is a unique feed in that it can provide protein, energy, and fiber. It is an excellent supplement for low quality hay or pasture because it supplies both protein and energy in one feed ingredient. Cottonseed is readily available in cotton producing regions. For every 218 kg. bale of lint produced there is about 363 kgs. of whole cottonseed (Willcutt and Mayfield, 1994). Cottonseed does not require processing

and can be fed whole to mature ruminants, reducing handling and equipment costs (Rogers & Poore, 1995).

Cottonseed quality is determined by harvest conditions, storage conditions, mechanical damage during harvesting or ginning, and moisture (Willcutt & Mayfield, 1994). Whole cottonseed is 23% CP and 90% TDN on a dry matter basis (NRC, 2000). Research indicates that whole cottonseed has a feeding value similar to a 20% CP mixture of corn and soybean meal and can be used as substitute in silage-based diets or with poor quality hay (Rogers and Poore, 1994; Rogers and Poore, 1995). The calcium content of cotton byproducts is low, so proper calcium supplementation should be provided to maintain an approximate 2:1 calcium to phosphorus ratio (Stewart and Rossi, 2010). The energy from whole cottonseed primarily comes from its fat content (Rogers and Poore, 1995). The fat in cottonseed has been shown to improve reproductive performance especially in thin cows, as the increased circulation of triglycerides and cholesterol may aid in steroidogenesis (Rogers and Poore, 1995). The protein combined with the fat and encased in the hull should provide for slow release in the rumen (Rogers & Poore, 1995). Early research indicated that 5 to 7 % of added fat in high-forage diets depressed fiber digestibility in steers (Erwin et al., 1956; Murphy and Morgan, 1983). Moore et al. (1986) found that utilization and digestibility of high forage diets is depressed when added fat exceeds approximately 5%, confirming previous recommendations. When fed at the recommend rate of 5% or less added fat to the diet the fat does not interfere with forage digestion, as does the starch in corn (Rogers and Poore, 2002). The CP in cottonseed is true protein which may be better for supplementing high-forage diets than a non-protein nitrogen such as urea (Rogers & Poore, 1995).

Whole cottonseed should not be fed to pre-ruminant calves and great care should be taken to avoid overfeeding bulls and developing heifers due to gossypol (Rogers and Poore, 1995). Feeding recommendations of whole cottonseed for brood cows are 0.5% of body weight or 20% of the diet on a dry matter basis (Rogers et al. 2002). For growing cattle whole cottonseed should be limited to 0.33% of body weight or 15% of ration on dry matter basis (Rogers & Poore, 2002) Cottonseed inclusion above 15% of the diet may reduce intake along with reductions in gain and feed efficiency (Rogers and Poore, 1995). Feeding cottonseed above 0.5% of cow body weight will supply excess dietary fat that can interfere with fiber digestion (Hill et al., 2008). However, a study conducted with dairy cows showed that cottonseed levels as high as 25% of the ration were beneficial (Coppock and Wilks, 1991).

The price of cottonseed is more susceptible to fluctuation than corn or soybeans per crop year; therefore, it may be over or underpriced relative to its feeding value each year (Rogers and Poore, 1995). The most economical time to purchase whole cottonseed is during the ginning season as it leaves the gin (gin run seed) rather than after it has been in storage (Rogers and Poore, 1995). Cottonseed does not flow well through an auger and for this reason cannot be stored in a grain bin (Rogers and Poore, 1995). Russell (1983) recommended storing cottonseed at less than 10% moisture to minimize risk of heating and mold development, specifically aflatoxin. Myer and Hersom (2018) recommend a more practical target of 14% moisture or less. Cottonseed should be stored under an open shed where it can be protected from precipitation but allow for air flow, ideally one with a concrete floor (Rogers and Poore, 1995).

One study showed that limit feeding oil seeds (4% of dry matter intake) to beef cows with low body condition scores improved their cycling before the breeding season (Stanko et al., 1997). A study conducted by Hill et al. (2008) found that when fed at the recommended levels of

0.05% of body weight, whole cottonseed stimulated hay intake. Hill et al. (2008) also found that cows had higher average daily gains (ADG) and body condition scores (BCS) when fed whole cottonseed at 0.5% body weight compared with a poured protein product. This study also showed that the apparent digestion of a hay and whole cottonseed diet by steers was unaffected by feeding whole cottonseed at 0.5% body weight, but free-choice feeding depressed organic matter and fiber digestion and is not cost effective (Hill et. al, 2008).

Cottonseed Meal

Cottonseed meal has been used successfully for over 100 years in areas of the country where cotton is produced, and cottonseed is processed (Blasi and Drouillard, 2002). After oil, cottonseed meal is the second most valuable and abundant byproduct of the crushing process (Blasi and Drouillard, 2002). Gossypol limits the use of cottonseed meal for swine or poultry, so it is almost always a less expensive protein source than soybean meal (Rogers and Poore, 1995). Soybean meal has about 17% more protein than cottonseed meal (Stewart and Rossi, 2010). Cottonseed meal is typically cheaper than soybean meal by 25-35% and has approximately 45% CP on a dry matter basis and 1.2% phosphorus (Stewart and Rossi, 2010). It also has similar rates of protein degradation as soybean meal and can replace it in most diets, except those of pre-ruminant calves (Stewart and Rossi, 2010). For example, 0.54 kgs. of cottonseed meal (41% CP) provide relatively the same amount of protein as 0.45 kgs. of soybean meal (48% CP) (Rogers and Poore, 1995).

There are three types of cottonseed meal: mechanically extracted, prepressed and solvent extracted, and direct solvent extracted (Rogers and Poore, 1995). All three forms have similar nutrient value, but direct solvent extracted has more free-gossypol (Rogers and Poore, 1995).

Most cottonseed processing plants have moved away from direct solvent extracting (Rogers and Poore, 1995). The nutrient content depends on the extraction method (Blasi and Drouillard, 2002). The greatest difference being in oil or fat content. Mechanically extracted cottonseed meal tends to have more residual oil than pre-pressed solvent or solvent extracted (Blasi and Drouillard, 2002). Because of the oil extracting process, cottonseed meal primarily has the bound form of gossypol (Blasi and Drouillard, 2002). The vast majority of cottonseed meal from U.S. plants is made using a process where cottonseed meats are separated from the hull, moistened, flaked, and cooked before going into an expander. From the expander, hulls are extracted, then desolventized, and toasted. This process binds most of the free gossypol (Blasi and Drouillard, 2002). The level of free gossypol in cottonseed meal has decreased nearly 50% since the 1960s and 1970s due to expander-solvent technology (Blasi and Drouillard, 2002).

Coppock (1987) found the nutritional protein degradability of cottonseed meal is similar to that of peanut meal, canola, and soybean meal for lactating dairy cows, and to that of canola meal and soybean meal for young calves. When increasing levels of cottonseed meal were added to low-quality native grass diets containing equal amounts of corn, there was a significant increase in digestibility (Hibberd et al, 1987). Other growth trials have supported this finding with either hay-based (Brown, 1991) or silage-based (Blasi and Drouillard, 2002) diets. Several feeding trials have been conducted to evaluate protein and energy levels of cottonseed meal relative to other protein sources and found that there were no differences between supplement sources and cow weight change or weaning weights (Coombs, 1996). Gonzalez et al. (1988) showed that small additions of cottonseed meal efficiently improved the utilization of low-quality forage and performance of lactating beef cows.

Cottonseed Hulls

Cottonseed hulls are primarily hemicellulose and lignin with almost pure cellulose linter fibers attached (Tharp 1948). Cottonseed hulls have relatively low nutritional value but are very palatable to cattle (Rogers and Poore, 1995). They are priced high in comparison to nutrient value and are not an economical feed source (Stewart and Rossi, 2010). Due to variable oil crush and high storage cost, cottonseed hull market prices are extremely volatile (Blasi and Drouillard, 2002). Cottonseed hulls have high transportation and storage costs due to low bulk density (Jacobs et al., 2020). Cottonseed hulls can be used as the sole roughage source in finishing diets (Rogers and Poore, 1995). Cottonseed hulls can be used as a hay replacement, 1.4kgs. of cottonseed hulls can replace 0.5 kgs. of average quality hay (Rogers and Poore, 1995).

Cottonseed hulls are often used in preconditioning rations to increase palatability and improve feed acceptance (Rogers and Poore, 1995). Cottonseed hulls change both the texture of rumen content and the digestion of other diet ingredients by increasing digesta passage rate (Hall and Kononoff, 2011). High grain diets that use cottonseed hulls report increased feed intake but reduced feed efficiency when compared to other roughage sources, such as hay (Rogers and Poore, 1995). Blasi et al. (2001) found that when incorporated in a traditional receiving diet, heifers fed a pellet containing cottonseed meal and cottonseed hulls consumed more feed than those that consumed alfalfa hay, were less efficient, but had similar daily gains. Rust and Owens (1982) evaluated the influence of various roughage sources on nutrient utilization by feeding a variety of roughage sources with whole corn. They found that starch digestion was the greatest in the cottonseed hull diet and that the hulls increased the digestibility of whole corn compared to alfalfa. This study confirmed Teeter et al. (1981) study where cottonseed hulls fed at high levels increased starch digestion by increasing rumination.

Numerous reports indicate that cottonseed hulls are a suitable source of roughage in beef cattle diets as long as there is sufficient protein, minerals and vitamins in the complete ration. There is no danger of gossypol toxicity from cottonseed hulls, as gossypol is found in the kernel portion of seeds (Rogers and Poore, 1995). Hulls are typically reported as having less than 0.049% free gossypol (Forster and Calhoun, 1995). They are very low in CP, calcium, and phosphorus (Stewart and Rossi, 2010).

Motes

Gin motes are immature or broken seeds with attached fibers. Gin motes can be marketed for re-ginning to reclaim some of the usable fiber (Rogers and Poore, 1995). Gins that reclaim motes will have less waste, as motes average 7.5 kgs. per bale of cotton (Thomasson, 1990). Some gins that do not have a mote press will include motes in their ginning byproduct improving its feeding quality (Rogers and Poore, 1995). Cotton motes have good nutritional value as a roughage source, with 45% to 50% TDN and 7% to 9% CP (Rankins, 2004). While gin motes have relatively good feeding value, they are often not available for use as cattle feed because they are typically marketed for re-ginning (Rogers and Poore, 1995).

Gossypol

Gossypol is a naturally occurring plant pigment that is found in cotton, okra, and plants in the Malvaceae family (Blasi and Droillard, 2002). It is found in localized pigment glands throughout the plant but is especially concentrated in the kernel portion of the seed (Rogers and Poore, 1995). Whole cottonseed contains 0.4 to 2.0% free gossypol (Blasi and Droillard, 2002). The level found in the plant is affected by the species, variety, growing conditions, and insect

pressure (Blasi and Droillard, 2002). In the cotton plant, gossypol provides the plant with some protection from predators that would feed on it due to its anti-insect and anti-fungal properties (Boatner, 1948; Beradi and Goldblatt, 1969). Gossypol exists as two stereoisomers (+) isomer or the (-) isomer. The (-) isomer has the greater biological activity of the two and thus is more toxic (Stewart and Rossi, 2010; Rogers et al. 2002).

Upland cotton varieties have less total gossypol as well as a lower percentage of (-) isomer gossypol than Pima varieties (Stewart and Rossi, 2010). The isomers exist in two states, bound and unbound. The unbound is the most biologically active, while bound is basically unavailable to the animal (Blasi and Drouillard, 2002). Whole cottonseed typically has 1.5%-2% gossypol all in the unbound form (Blasi and Drouillard, 2002). Mastication and exposure to ruminant microbes allows for deactivation, binding, and degradation that renders gossypol unavailable to the animal (Blasi and Drouillard, 2002). Nonruminant animals are very susceptible to gossypol because they have no means of detoxifying it. Ruminants are provided some protection from gossypol due to their mechanism of digestion. Physical breakdown via mastication, chemical breakdown during digestion, and prolonged exposure to rumen microbes allow ruminants to utilize feeds containing gossypol (Blasi and Drouillard, 2002). Ruminants are less susceptible because rumen microorganisms can detoxify free gossypol by binding it to soluble proteins in the rumen (Reiser and Fu, 1962). Protein that has bound to gossypol in the rumen is unavailable for digestion and cannot be utilized by the animal (Morgan, 1989).

There is no diagnostic test for gossypol poisoning and its symptoms are similar to other maladies. Plasma gossypol levels have been correlated to the amount of cottonseed product, such as whole cottonseed or cottonseed meal, being fed (Blasi and Drouillard, 2002). Clinical signs of gossypol toxicity can include decreased dry matter intake, decreased milk production, panting,

elevated heart rate, ruminal stasis, severe abomastisis, hemoglobinuria and sudden death (Rogers and Poore, 1995). The most frequently noted issue arising from gossypol in beef cattle is its effect on reproductive function in males, when fed at excessive levels. Abnormal morphology and reduced sperm motility in pubescent and growing bulls is well documented (Chase et al, 1989; Lim et al., 2019; Arshami and Ruttle, 1988; Risco et al. 1992). Gossypol, specifically the (-) isomer, affects the germinal epithelium and mitochondria in the tail of sperm, reducing sperm count and causing structural abnormalities (Randel et al., 1992). Gossypol induced infertility is reversible and once gossypol is removed from the diet normal spermatogenesis resumes, and normal sperm are produced within sixty days (Rogers and Poore, 1995).

Mature bulls are less susceptible to gossypol induced infertility. Long-term effects on young bulls that have been fed excessive amounts of cottonseed products is not well documented. No reported data shows impaired fertility of bulls when whole cottonseed or cottonseed meal are fed at the recommended amount of 0.5% of body weight or less (Stewart and Rossi, 2010).

Gossypol analysis is a difficult procedure with a number of compounds, such as the oxidation products of hydroxylated unsaturated fatty acid triglycerides, that can interfere with analysis results (Blasi and Droulliard, 2002; Stipanovic et al., 1984). This is why analysis of mixed feeds often have less consistent results than a pure cottonseed sample (Blasi and Droulliard, 2002). The American Oil Chemists' Society Official Method Ba 8-78 (AOCS, Urbana, IL) is one assay that can be performed to quantify total gossypol levels. Enzyme-linked immunosorbent assays and other immunochemical methods such as assays utilizing polyclonal and monoclonal antibodies can be used in quantifying both free and bound-gossypol (Wang, 1999; Wang, 2004). High Performance Liquid Chromatography (HPLC) is more accurate and

can be used to measure gossypol in mixed feeds with greater success (Blasi and Droulliard, 2002). There are very few commercial labs that carry out gossypol analysis (Blasi and Droulliard, 2002).

Due to its form, whole cottonseed often has increased retention time in the rumen helping to contribute to less available gossypol (Blasi and Droulliard, 2002). Roasting, extruding, and cracking has improved digestibility, but also increases available free gossypol (Blasi and Droulliard, 2002). This is especially true of Pima seed. Pima seed already contains more gossypol than upland varieties and has less linter fibers which increase rumen retention. Due to its lack of linter fibers, Pima seed is often ground to avoid having the seed pass undigested into the feces. Grinding Pima seed exposes more gossypol glands to the rumen environment more quickly than if the seed were whole. The quick exposure to more gossypol glands decreases the rumen's ability to render the gossypol unavailable (Stewart and Rossi, 2010; Blasi and Droulliard, 2002).

Chemical Residues

Chemical residue tolerances are not well established for most crop protection products used on cotton (Buser, 2001). Herbicides are the most often applied pesticides to cotton in the United States with 93% of planted acres having herbicides applied, followed by 65% of planted acres receiving "other chemicals" which includes defoliants, and insecticides applied to 56% of planted acres. (NASS, 2020). The most common herbicide active ingredient applied is glyphosate followed by dicamba diglycolamine salt (NASS, 2020). In addition to defoliants, chemical desiccants are also used in cotton production and can help to prepare plants for harvest

by causing the rapid loss of water from plant tissue and subsequent death (Williford, 1994). Desiccants are utilized most often with stripper harvesting (Crawford et al., 2001).

Defoliant is primarily used with picker harvesting (Crawford et al., 2001). Defoliant is another chemical used in cotton production. Defoliant works to induce abscission (leaf shedding) of cotton plants. Defoliation removes the leaves, eliminating the main source of trash. This improves lint grades, prevents boll rot, improves picker efficiency, allows for early harvesting, reduces moisture, and improves storage in modules (Dodds et al., 2016). Defoliant is either classified as herbicidal or hormonal, and both work by triggering the plant to produce ethylene, resulting in leaf drop. Herbicidal defoliant stimulates ethylene production through injury (Dodds et al., 2016).

The use of arsenic acid as a cotton defoliant began in 1956 and was the primary cotton defoliant for almost 40 years (Crawford et al., 2001). Arsenic is no longer utilized in cotton defoliant; therefore, it is no longer a concern when feeding cotton byproducts (Stewart and Rossi, 2010). A study in Georgia evaluated the presence of pesticide residue in gin byproduct from 21 gins and found that tribufos (“DEF”, Bayer CropScience, Research Triangle Park, NC), a common defoliant, was the only detectable pesticide residue (Stewart et al., 1998). The average level found in this study was 4.49 ppm which is less than the cottonseed hulls tolerance of 6 ppm, but higher than the whole cottonseed tolerance of 4 ppm as set by the Environmental Protection Agency (Stewart et al., 1998). There are no tolerance levels established for gin byproduct (Stewart and Rossi, 2010). Processing may metabolize, detoxify, or destroy pesticide residues in gin waste (Buser, 2001; Thomasson, 1990; Winterlin et al., 1986)

Composting is one of the most effective processes for reducing the amount of pesticide residues, but unfortunately reduces feeding value (Winterlin et al., 1986) Mixing cotton gin

byproduct with cottonseed and extruding it for livestock rations, can nearly eliminate some pesticide residues and reduces others (Thomasson et al., 1998; Buser, 2001). Extrusion applies heat, pressure, and shear to the material being extruded and internally mixes the cotton gin byproducts creating a more uniform product. Additionally, the product is heated due to friction (Buser, 2001). In a study by Buser (2001), cottonseed was added to allow the material to flow through the extruder. The minimum concentration of cottonseed needed in the mixture to maintain uniform material flow was 25% (Buser, 2001). Extrusion test indicated that some residue levels were diminished by extrusion and then further reduced due to the effects of dilution from the addition of cottonseed (Buser, 2001). The extrusion process did not affect most of the nutritional values; however, soluble protein was reduced after the first extrusion and CP was reduced after subsequent extrusions but incorporating more cottonseed could offset the loss (Buser, 2001). In a similar study, Thomasson et al. (1998) reported that extrusion did not reduce feeding value, and that the addition of cottonseed actually improved nutritive value by increasing CP and energy content. Residue levels decreased as the percentage of cottonseed in the mixture increased, likely due to the dilution effect (Buser, 2001). Because of the potential for chemical contamination, great care should be taken when cotton byproducts are being fed to cattle for slaughter (Rogers and Poore, 1995)

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CHAPTER 2: AVAILABILITY AND MANAGEMENT OF COTTON BYPRODUCTS IN NORTH CAROLINA

Abstract

Whole cottonseed and cotton gin byproduct (also known as gin trash or cotton burrs), are known to be economical feed ingredients for beef cattle diets. There are several sources of information available to producers regarding the feeding of cotton byproducts; however, there is little information on the local supply chain and availability of these products. The objective was to survey cotton gins in North Carolina to determine how whole cottonseed and cotton gin byproduct are marketed. A 19-question survey was developed using Qualtrics survey software and emailed to all cotton gins in the state. Those who failed to respond to the weblink were contacted by phone. This resulted in a 73.5% response rate (n=25 responses). Data were analyzed using the reporting feature of Qualtrics. On average, 7,366 metric tons of cottonseed and 1,187 metric tons of gin byproduct are produced per gin during a typical season. All respondents reported that the majority of their whole cottonseed is marketed out-of-state as livestock feed. All respondents reported that they either already sell or would consider selling cottonseed locally as cattle feed. In contrast, 78.0% of respondents reported that the majority of their gin byproduct stays in the state, with 40.0% being sold as cattle feed and the remaining 60.0% either being stockpiled and allowed to decompose on-site at the gin or marketed for use as compost. Of the respondents, 95% already sell gin byproduct locally as cattle feed or would consider doing so. The majority of respondents (92.0%) agreed to be added to a directory to be distributed to cattle producers. This survey demonstrates that North Carolina cotton gins have

cotton byproducts available and that they are interested in selling these locally to cattle producers.

Introduction

Cotton byproducts have long been used as livestock feed in both the dairy and beef cattle industries. In recent years cotton byproducts have been revisited as an alternative cattle feed in North Carolina. This is in part due to whole cottonseed's often reasonable price and its ability to supplement energy and protein in cattle diets. This recent interest was also prompted by forage shortages due to droughts and flooding that occurred throughout the state during Hurricanes Matthew and Florence. Additionally, some commodity dealers and commercial feed companies in the state are now distributing gin byproduct. Gin byproduct can be utilized as a hay substitute as it has similar nutrient qualities as low-quality hay (Lalor et al., 1975). While there has been increased interest, it remains a poorly understood feed resource in terms of both feeding value and supply chain (Rogers et al., 2002). This is likely due, in part, to its lesser value in comparison with cotton lint and seed which have historically received more attention in terms of research and market tracking (Castleberry and Elam, 1998).

The amount of cotton byproducts generated can be estimated based on some known averages for example, Willcutt and Mayfield (1994) noted that for every 281 kg. bale of lint produced there is approximately 363 kgs. of whole cottonseed generated. The amount of gin byproduct generated can also be estimated by assuming 34-68 kgs. of trash material is created for every 218 kg. bale of cotton lint produced from spindle harvested seed cotton (Parnell et al., 1994). Production and market data is available for whole cottonseed since it is classified as a

commodity product. Cotton gin byproduct is generally considered a waste product; therefore, no production or market information is published.

Purpose of the Study

The purpose of the study was to determine how whole cottonseed and cotton gin byproduct are market by cotton gins in North Carolina. The ultimate purpose of the study was to gather information about the marketing of cotton byproducts in North Carolina in order to revise the Extension Feeding Guidelines for Cotton Byproduct Feeds. Another objective of this study was to create a directory of cotton gins that are interested in selling cotton byproducts locally to cattle producers. This directory would be disseminated to extension personnel and cattle producers across the state.

Through a quantitative study the following research questions were addressed:

1. How many 218 kg. bales of cotton are ginned per gin during one ginning season in North Carolina?
2. How much whole cottonseed and cotton gin trash is produced per gin per ginning season?
3. Is the majority of whole cottonseed and cotton gin trash being marketed in-state or out-of-state?
4. What is the majority of whole cottonseed and cotton gin trash used for once sold?
5. Would cotton gins consider selling whole cottonseed and cotton gin trash locally for use as cattle feed?
6. Are there any barriers preventing cotton gins from selling whole cottonseed and cotton gin trash locally for use as cattle feed?

Research Design

The survey was designed to understand how whole cottonseed and cotton gin trash are marketed in North Carolina. A descriptive census research approach was utilized to investigate this objective. Qualtrics Survey Software was utilized to create the questionnaire and for data collection. The survey was either completed via email or over the phone.

Population and Sample

The population of interest for this study was all 34 operating cotton gins in North Carolina. A list of these cotton gins was obtained through the Southeast Gins May 2019 Directory published by the Southeastern Cotton Ginners Association, Inc. All of the cotton gins in North Carolina are members of this association. Because our study population was so small, no sampling frame was required. All 34 cotton gins in our population were contacted making this a census design. Respondents were required to be either the owner or operator of the gin. There are four main sources of error that arise in survey-based research. These are: sampling error, coverage error, measurement error, and non-response error (Dillman et al., 2009). Due to the census design of the study granting the ability to survey the entire population, sampling error has been eliminated.

The survey was distributed by email and also by phone. Having two forms of questionnaire distribution allowed everyone in the population to be reached, helping to reduce any coverage errors (Dillman et al. 2009). Measurement errors in a survey can be caused by both the respondent and the questionnaire/interviewer. To help control for measurement errors the questionnaire was reviewed by two members of Cotton Incorporated's Agricultural and Environmental Research Staff for face and content validity. Face validity is a subjective

judgement that evaluates the appearance of the questionnaire in terms of readability, clarity, and feasibility (Taherdoost, 2016). Based on their recommendations the phrasing “cotton gin trash” and “gin trash” were utilized in place of “gin byproduct” to improve question clarity and comprehension.

Non-response errors are a type of non-sampling error and occur when those who do not respond differ from those who do respond (Dillman et al., 2009). In an effort to reduce this type of error questionnaires were sent via email and followed up by phone. This was done to ensure that non-response was not due to limited computer skills or communication preference. Qualtrics Survey Software was also chosen based on its ability to format the questionnaire for both desktop and mobile devices. This was done to ensure that gin operators that rely on their mobile devices to check email would have no barriers to complete the questionnaire. Additionally, in an effort to reduce non-response errors and improve response rate email reminders were sent to non-respondents every 2 weeks up to 5 times. After five email reminders, non-respondents were contacted via phone.

Instrumentation

The census instrumentation was developed by the researcher and can be found in Appendix A. The census instrument was composed of five sections: cotton gin contact information, questions regarding whole cottonseed marketing, questions regarding cotton gin trash marketing, questions regarding gin mote marketing, and a request for permission to include the cotton gin in a directory. The census instrument contained both open-ended and close-ended questions. Open-ended questions were used to gather production volume information. The

instrument was submitted to the North Carolina State University Institutional Review Board (IRB) and received exemption status.

Before respondents were admitted to the questionnaire, they were required to complete a consent form. The consent form provided the following information: title of the study, principle investigator, faculty point of contact, funding source, study purpose, participation eligibility requirement, risks and benefits of participation, and confidentiality management. In order to be admitted into the questionnaire participants had to select “I consent, begin survey” at the end of the form. One of the goals of this census was to create a directory of cotton gins interested in selling cotton byproducts locally as cattle feed. The first section of the questionnaire was used to gather cotton gin contact information in order to meet our goal of creating a directory. Name of respondent, e-mail address, and the physical address of the cotton gin were recorded.

The second section asked respondents about their whole cottonseed production. The first question of this section was open-ended and asked respondents to list how much cottonseed is produced at their gin per ginning season during a typical year. The following question asked respondents if the majority of their whole cottonseed stays in North Carolina or is marketed out-of-state. The next question was a multiple-choice type question and asked respondents what the majority of their whole cottonseed was used for (crushed for oil, sold as cattle feed, or other). If respondents selected “other” to any question during the census they were provided with a text box to supply their answer. Following this, respondents were asked if they would consider selling cottonseed locally as cattle feed. The answer choices to this question were “yes”, “maybe”, “no”, and “We already sell cottonseed locally as cattle feed”. If respondents selected “no” to this question they were prompted to complete an open-ended question regarding why they would not consider selling cottonseed locally as cattle feed.

The third section of the census collected information about gin trash. This section followed a similar format as the previous section starting with the open-ended question regarding the amount of gin trash produced by their gin during a typical ginning season. The following questions asked where the gin trash is marketed (in-state, out-of-state, or never leaves the gin), what is the gin trash being used for, what form of gin trash is being marketed (bales, modules, or loose), would the gin consider selling gin trash locally as cattle feed, and if the gin already sells gin trash locally as cattle feed, do they arrange shipping.

The fourth section asked questions pertaining to gin mote. The first question in this section asked if the gin has a mote press. If a cotton gin does not have a mote press, gin mote is included in the gin's gin trash. The follow questions asked how the gin markets mote (sold for re-ginning, sold locally as cattle feed, or other), would the gin consider selling gin mote locally as cattle feed, and if the gin currently sells gin mote as cattle feed do they arrange shipping. The final section and final question ask respondents if they are interested in selling cotton gin byproducts locally as cattle feed would they agree to be added to a cotton gin directory to be provided to North Carolina cattle producers.

Data Collection

For this survey, a modified version of Dillman's Tailored Design Method was used (Dillman et al., 2009). The Tailored Design Method or TDM was based off of a sociological theory used to explain why some people are more likely to engage in some behaviors than others (Dillman et al., 2009). The TDM emphasizes the importance of several coordinated contacts with respondents, personalized correspondence, providing explanation on how the survey would be useful to others, and providing contact information to help establish the legitimacy of the

survey. Dillman (1978) found that when the Tailored Design Method, then called the Total Design Method, was utilized mail and telephone response rates were 60-70% for most populations.

On March 2nd, 2020 an email was generated using the Distribution feature in Qualtrics and was sent to all 34 study participants that introduced the researcher, explained the study, outlined the potential impacts of the study, and included the survey link. In the email signature the researcher included their title, email address, phone number, and a headshot. This was done to help establish the validity of the survey. Reminder messages were sent to non-respondents or unfinished respondents on March 18th, March 23rd, April 6th, and April 20th. In the final email reminder, it was expressed that researcher would begin contacting non-respondents by phone on April 27th. There were 18 responses collected via the online survey link sent by email. This resulted in a 52.9% response rate for the online data collection.

On April 27th all non-respondents were called on the telephone, and messages were left via voicemail if there was no answer or with the receptionist if the gin manager was not available to take the call. Those who were unable to be reached on April 27th were called again, two weeks later. Due to the seasonality of cotton ginning, non-respondents were contacted by telephone for the final time on October 26th, 2020. When respondents were contacted by telephone the questionnaire was read aloud to respondents and answers were recorded by the researcher. This included the consent form which respondents verbally agreed to before the census began. There were 7 telephone responses recorded resulting in an overall response rate of 73.5%.

Data Analysis

Data were exported from Qualtrics to Microsoft Excel for content and data analysis. Descriptive statistics were utilized to analyze the data. Percentages, frequencies, standard deviations, means, and sums were utilized to summarize the findings.

Findings

1. How many 218 kg. bales of cotton are ginned per gin during one ginning season at your gin?

All 25 respondents (n=25) answered this question. The range was 11,000 – 55,000 bales. The mean was 26,852 bales with a standard error of 2,731 and a standard deviation of 11,905. The total number of bales ginned by respondents was 510,191.

2. In a typical year, how much cottonseed is produced per gin during one ginning season?

Two respondents did not provide an answer for this question (n=23). Some respondents listed ranges as their response. When this occurred the average of the range was taken. For example, if 10,000-20,000 metric tons was listed, 15,000 metric tons was used. The mean was 7,192 metric tons with a standard error of 822 and a standard deviation of 4,027. The total tons recorded for these 22 respondents was 172, 610 metric tons of cottonseed.

3. Where does the majority of this whole cottonseed go?

Table 1 summarizes the findings from this question. Once again two respondents failed to answer this question (n=23); however, they were different respondents than the two who failed to answer question #2. All 23 respondents reported that the majority of their whole cottonseed goes out-of-state (100%).

Table 1. Location of whole cottonseed marketed by North Carolina gins (N=23)

Location of Cottonseed Marketing	N	%
Out-of-state	23	100
In-state	0	0

4. *What is the majority of this whole cottonseed being used for?*

Table 2 characterizes what the whole cottonseed is being used for. All respondents provided a response to this question (n=25) and all 25 reported that the majority of their whole cottonseed is utilized for livestock feed (100%). Three respondents that talked with the researcher on the telephone, verbally expressed that most of their whole cottonseed is sold via a broker to be utilized by Midwestern dairies.

Table 2. Utilization of whole cottonseed produced by North Carolina gins (N=25)

Cottonseed Use	N	%
Crushed for Oil	0	0
Livestock Feed	25	100
Other	0	0

5. *Would this gin consider selling cottonseed locally as cattle feed?*

A summary of the results from question #5 can be found in Table 3. Of the respondents 40% (n=10) said they would consider selling cottonseed locally, 12% (n=3) answered “maybe”, 0% (n=0) answered “no”, and 48% (n=12) answered “We already sell cottonseed locally as cattle feed”.

Table 3. North Carolina gins that would sell cottonseed locally as cattle feed (N=25)

Would this gin consider selling cottonseed locally?	N	%
Yes	10	40
Maybe	3	12
No	0	0
We already sell cottonseed locally as cattle feed.	12	48

6. If this gin currently sells cottonseed locally, do you arrange shipping?

Table 4 summarizes the data collected in question #6. Of the respondents 15% (n=3) reported that they do arrange shipping for local cottonseed orders, 80% (n=16) reported that they do not arrange shipping, and 5% (n=1) responded with “other”. The respondent that answered “other” was given the opportunity to explain with an open-ended response. This respondent replied “No, we use a broker. Most goes for dairy feed.”

Table 4. North Carolina cotton gins that arrange shipping for whole cottonseed (N=20)

Does this gin arrange shipping for cottonseed?	N	%
Yes	3	15
No	16	80
Other	1	5

7. In a typical year, how much gin trash is produced at this gin in one ginning season?

As this was an open-ended question, there were a variety of responses received both numeric and text. There were 20 numeric responses. The range of these responses was 454-2722 metric tons. The mean was 1,187 metric tons with a standard error of 131 and a standard deviation of 586. The total tons of gin trash recorded from these 20 responses was 23,732 metric

tons. This question received 5 free response answers which were as follows: “Absolutely no clue, we do not weigh” (n=1), “I have never measured this to give a good answer we feed our cattle every day during the season” (n=1), and two respondents answered, “Not sure” (n=2).

8. *What is this gin currently doing with its gin trash?*

This data from question #8 is summarized in Table 5. Of the 25 respondents 40% (n=10) reported that the majority of their gin trash is sold as cattle feed, 32% (n=8) selected “other”, and 28% (n=7) reported they stock-pile their gin trash and allow it to decompose on-site. Of the respondents who selected “other” their responses are as follows: “feeding cattle”, “giving it away”, “given away as cattle feed”, “Usually stock-pile and decompose in 2019 we gave it away”, “Stock-piled and then spread back on gin owner’s farmland”, “We don’t sell any but do give away some as cattle feed, compost, and the rest stays at the gin”, “We give it away. Some is used for compost, fertilizer, and cattle feed”, and “80% sold to composter 20% given away as cattle feed (only charge loading fee)”. Respondents were permitted to select more than one answer.

Table 5. Gin trash utilization by cotton gins in North Carolina (N=25)

Gin Trash Utilization	N	%
Stock-piled and allowed to decompose on-site	7	28
Managed Composting	0	0
Sold as cattle feed	10	40
Other	8	32

9. *If your gin currently markets gin trash as cattle feed, what form is being sold?*

Results from question #9 are characterized in Table 6. Out of the 19 respondents that answered this question 5% (n=1) responded that they marketed their gin trash in the form of modules, 21% (n=4) reported that they marketed bales of gin trash, and 74% (n=14) reported that they marketed gin trash in the loose form.

Table 6. Form of gin trash marketed (N=19)

Form of Gin Trash Marketed	N	%
Bales	4	21
Modules	1	5
Loose	14	74
Other	0	0

10. *Where does the majority of your gin's gin trash go?*

Responses from question #10 are summarized in Table 7. Of the respondents (N=23) 78% (n=18) reported that the majority of their gin trash stays in-state, 18% (n=4) reported that their gin trash never leaves the gin, and 4% (n=1) said the majority of their gin trash goes “out-of-state”.

Table 7. Location of gin trash marketed by North Carolina Gins (N=23)

Location of Gin Trash Marketing	N	%
In-state	18	78
Out-of-state	1	4
Nowhere, it stays at the gin.	4	18

11. Would you consider selling gin trash locally as cattle feed?

Responses from question #11 are summarized in Table 8. Of the respondents (N=23) the 57% (n=13) said they would consider selling gin trash locally as cattle feed, 30% (n=7) already sell gin trash locally as cattle feed, 9% (n=2) responded with “maybe”, and 4% (n=1) responded that they would not consider it.

Table 8. Likelihood of North Carolina gins to sell gin trash locally (N=23)

Would this gin consider selling gin trash locally?	N	%
Yes	13	57
Maybe	2	12
No	1	4
We already sell gin trash locally as cattle feed.	7	30

12. If you would not consider selling gin trash as cattle feed, why?

The one respondent that selected “no” to the previous question was supplied with a text box for free response. The respondent reported “It provided greater value as organic material being spread on the sandier farms to increase cotton yields”. “It” referring to gin trash.

13. If you currently sell gin trash as cattle feed, do you arrange shipping?

Results from this question are characterized in Table 9. The majority of respondents, 71% (n=12), responded that they do not arrange shipping for gin trash with 29% (n=5) reporting that they do arrange shipping.

Table 9. Incidence of North Carolina gins arranging shipping for gin trash (N=17)

Does this gin arrange shipping for gin trash?	N	%
Yes	5	29
No	12	71
Other	0	0

14. Does your gin have a mote press?

All gins that responded to this question (N=23) have a mote press. This indicates that motes are not included in 100% of the gin trash generated by these gins.

15. If your gin has a mote press, how do you market mote?

Table 10 summarizes the responses of this question. Of the 23 respondents 21 reported that they sell their mote for re-ginning (91%). The remaining 2 respondents answered “other”. Only one open-ended response was recorded, and it stated, “belongs to someone else, not the gin”.

Table 10. Methods of gin mote marketing in North Carolina (N=23)

How does your gin market mote?	N	%
Sold for re-ginning	21	91
Sold as cattle feed	0	0
Other	2	9

16. Would you consider selling gin mote locally as cattle feed?

Data from this question is characterized in Table 11. The majority of respondents, 41% (n=9), said they would not consider selling gin mote locally as cattle feed. Of the remaining respondents, 36% (n=8) answered “yes” and 23% (n=5) responded “no”.

Table 11. Likelihood of North Carolina cotton gins selling gin mote locally as cattle feed (N=22)

Would you consider selling gin mote locally as cattle feed?	N	%
Yes	8	36
No	9	41
Maybe	5	23

17. If you are interested in selling cottonseed and cotton gin byproducts locally, would you like to be added to our cotton gin directory to be provided to North Carolina cattle producers?

The majority (88%) of census participants requested to be added to the directory. Of the remaining participants 1 answered “other” and 2 responded with “no”. The participant that selected other provided the addition information that their gin was interested in only selling gin trash locally and not whole cottonseed.

Table 12. North Carolina cotton gins that requested to be added to our directory (N=24)

Would you like to be added to our directory?	N	%
Yes	21	88
No	2	8
Other	1	4

Discussion and Conclusion

This census of North Carolina cotton gins was conducted with Dillman's Tailed Design Method in mind. This method suggests that to obtain the highest response rates four points of contact should be made (Dillman et al., 2009). In the case of this study, more than four contacts were made. Due to the seasonality of cotton ginning, timing may have played a major role in response rate. Cotton gins are most active beginning in late September or early October and finish up the ginning season in January. The first contact for this census was made in the spring, outside of the ginning season and later in October at the beginning of ginning season to try to accommodate the seasonality. Oftentimes gins are very busy during the season and managers do not have the time or want to take the time to complete a survey. In contrast, outside of the ginning season it is often more difficult to make contact with gin managers as they may not be at the gin every day.

Respondents were asked to answer questions based on a "typical year". During phone interviews many participants noted that there have been notable fluctuations in bales ginned in the last decade making it hard to say what a typical year is. During the 2020 ginning season 541,800 bales of cotton were ginned in North Carolina (NASS, 2021). The previous three year's totals were 1,061,150 bales in 2019, 703,500 in 2018, and 763, 300 bales in 2017 (NASS, 2021). The average of these 4 years is 767,437.5 with a standard error of 108,506 and 73.5% of this 4-year average is 564,066. Based on the respondent's answers, the total number of 500 lbs. ginned was 510,191. Considering that this number can be assumed to reflect only 73.5% of the bales ginned in North Carolina. Based on these calculations it appears that the respondents accurately estimated these numbers based on a typical year and their responses corroborate with the USDA Cotton Ginnings publication (NASS, 2021).

Whole cottonseed differed drastically in terms of marketing and marketing location when compared to gin trash. The majority of whole cottonseed leaves North Carolina while the majority of gin trash stays within the state. Additionally, all respondents reported that the majority of their whole cottonseed is used for livestock feed while gin trash is not currently being used for livestock feed at the same rate. Most gins are currently selling some whole cottonseed to local cattle producers, but far fewer are selling gin trash. It appears that the majority of gins are interested in marketing gin trash locally as cattle feed. Only one gin was not interested in being included in the directory and this gin cited that they already had all the business they could handle when it came to selling gin trash.

It is noteworthy that 43% of respondents were unable to provide an amount of gin trash that they produce with many responding “I’m not sure” or “we don’t weigh”. This further confirms that gin trash or gin byproduct is still viewed as a waste product by cotton gins in North Carolina. It also became very clear through phone conversations and the number of respondents that selected “other” to question #8 that most cotton gins do not want to be associated with selling gin trash. The gins made it very clear that they typically charge a loading fee, but are giving away the actual gin trash for free. Gins could be making this distinction to avoid liability on the part of the gin. Cottons gins do not conduct nutrient analysis on gin trash or whole cottonseed, nor do they test for chemical residues before marketing these products.

During phone interviews, a couple of gins noted that in the past they directly applied their gin trash to the land until glyphosate resistant pigweed became a problem. Because of this, they now give their gin trash away. According to a study by Norsworthy et al. (2009) palmar amaranth, a type of pigweed, is the most frequently found broadleaf weed seed in gin trash. Palmar amaranth seeds were found to be viable even after 2 years of composting when located in

the surface layer of the trash pile. This poses an issue for cotton producers who directly apply, gin trash to their fields. Unfortunately, the majority of gins in North Carolina are marketing loose gin trash. Gin trash has a low bulk density that can make it difficult to work with or haul in its loose form without a dump bed truck.

This study has important implications for North Carolina cattle producers residing in cotton producing regions. This study has shown that overall, North Carolina cotton gins have cotton byproducts and are willing to sell them or give them away locally. Depending on commodity pricing, this has the potential to improve profitability for producers by reducing feeding costs and improve profitability of cotton gins by providing them with a market for gin byproducts.

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CHAPTER 3: EVALUATION OF COTTON GIN BYPRODUCT AND WHOLE COTTONSEED IN DIETS FOR GROWING BEEF STEERS

Abstract

Cotton byproducts, such as whole cottonseed and cotton gin byproduct can be utilized as cattle feed. In cotton producing regions these byproducts are often accessible, but underutilized. The objective of this study was to evaluate the feeding value of whole cottonseed and cotton gin byproduct relative to a diet of corn silage supplemented with ground corn and soybean meal. A feeding trial was conducted using 56 yearling steers with a starting body weight (BW) of 288 ± 3.8 kgs. This was a randomized block experiment with steers blocked by weight and treatments randomly assigned and replicated within each pen. Treatment 1 (TRT 1) served as the control diet and was made up of corn silage supplemented with ground corn and soybean meal. Treatment 2 (TRT 2) replaced some of the corn and soybean meal with whole cottonseed (15% of the diet DM). Treatment 3 (TRT 3) replaced some of the corn silage with cotton gin byproduct (25% of the diet DM). Treatment 4 (TRT 4) was a combination diet that replaced some of the corn and soybean meal with whole cottonseed (15% of the diet DM) and some of the corn silage with cotton gin byproduct (25% of the diet DM). All diets were formulated to have the same nutrient content. Diets were fed as a total mixed ration and a slick bunk management style was used. Steers were fed the treatment diets for 84 days with blood samples being drawn every 28 days. Daily dry matter intake (DMI) for each treatment was as follows: TRT 1 was 8.8 kg, TRT 2 was 8.5 kg, TRT 3 was 11.3 kg, and TRT 4 was 10.3 kg (SEM=0.24). Dry matter intake did not differ between TRT 1 and TRT 2 ($P>0.5$). Average daily gain was highest for TRT 3 (1.5 ± 0.1 kgs.). Average daily gain did not differ between TRT 1 (1.3 ± 0.05 kgs.), TRT 2 (1.2 ± 0.05 kgs.), or TRT 4 (1.3 ± 0.05 kgs.). Feed conversion ratios were lowest for TRT 1 (6.8 ± 0.5) and

TRT 2 (6.8 ± 0.5), which did not differ. Feed conversion ratios for TRT 3 and TRT 4 were 8.7 ± 0.5 and 8.2 ± 0.5 , respectively. BUN concentrations were lowest in TRT 1 (3.4 ± 0.14 mM). All treatments saw an increase in BUN concentrations over time that followed a polynomial regression. This study demonstrates that cotton byproducts can be utilized in growing cattle diets in place of some corn, soybean meal, and corn silage while resulting in similar or enhanced performance.

Introduction

Cotton ginning produces two major byproducts, whole cottonseed and cotton ginning byproduct. Whole cottonseed has more value than cotton ginning byproduct due to its high protein and fat content, making it suitable to be crushed for oil and protein meal. This higher value of whole cottonseed results in more available market data and increased research interest. Whole cottonseed is widely utilized in dairy cattle diets and has been for a number of years. Cottonseed has a high value as a feed ingredient due to its ability to provide protein, energy, and fiber to cattle diets. Whole cottonseed is 23% crude protein (CP) and 90% total digestible nutrients (TDN) on a dry matter basis (NRC, 2000). Whole cottonseed, when fed at 0.5% of BW can stimulate hay intake (Hill et al., 2008). Additionally, whole cottonseed has been shown to outperform poured protein products (protein tubs) in their ability to increase ADG and body condition score (BCS) (Hill et al., 2008).

Cotton ginning byproduct creates a disposal issue for gins that is often costly. It has been estimated that the cotton ginning industry spent between \$15-25 million on ginning byproduct in 1994 (Parnell et al.) The nutrient content of cotton ginning byproduct can vary. There are many misconceptions surrounding cotton ginning byproduct. One of these is that it is low in crude

protein and feeding value. While this may be true in some instances, there are a variety of studies that demonstrate cotton ginning byproduct is not low in crude protein. The NRC (2000) reported that cotton ginning byproduct is 7% CP and 44% TDN while Kennedy and Rankins (2008) reported 12.4% CP. Additionally, a 1997 analysis of cotton gin byproduct from 26 Georgia gins found CP to range from 7.4% to 15.8% and TDN from 11.4% to 62.2% (Stewart et al., 1998).

Studies show that cotton gin byproduct is most valuable when fed as part of the energy source in a diet rather than the sole source of energy (Erwin and Roubicek, 1958; Sagebiel and Cisse, 1984). While these studies show that cotton gin byproduct can be used without adverse effects, a 2020 study conducted by Warner et al. demonstrated that a cotton gin byproduct diet outperformed the control diet in ADG, DMI, final BW, dressing percentages, and had no differences in gain to feed ratios.

Materials and Methods

Experimental procedures utilized in this trial were approved by the Institutional Animal Care and Use Committee at North Carolina State University (NCSU). A steer growth trial was conducted to evaluate the performance of whole cottonseed and cotton ginning byproduct in cattle diets.

Treatment of Animals

Fifty-six purebred yearling Angus steers were selected from a group of eighty-three yearling steers at the NCSU Butner Beef Cattle Field Lab. Steers were selected based on temperament and weight. While no quantitative temperament measurements were taken, temperament observations were recorded during an initial weight day that occurred two months

prior to the study. Steers with negative temperament observations were not selected. Initial steer weights were utilized to create pens that had less than a 23 kg. difference between the lightest and heaviest steer. The steers received Bovi-Shield Gold 4 (Zoetis Inc., Kalamazoo, MI) and Vision 7 with SPUR (Merck Animal Health division of Intervet Inc., Omaha, NE) at weaning approximately 7 months prior to the study. Six weeks prior to the trial start date all steers were treated to eliminate internal and external parasites (Dectomax Pour-On, Zoetis Inc., Kalamazoo, MI and Safe-Guard, Merck Animal Health division of Intervet Inc., Madison, NJ). Four weeks prior to the start of the study, steers were blocked by BW into 7 pens with 8 steers in each pen. The 8 lightest steers were assigned to Pen 1, steer body weight increased per pen with Pen 7 being assigned the 8 heaviest steers. Pens were equipped with Calan gate electronic feeders (American Calan, Northwood, NH), 1 automatic water bowl per pen, and slotted floors. During this four-week acclimation period steers were fed corn silage.

Two steers per pen were randomly assigned to 1 of 4 treatment diets, resulting in 14 steers per treatment. Initial (d 0) and final (d 84) weights were determined on all steers by weighing on two consecutive days prior to feeding at approximately 0830. The mean weight of the two consecutive days was utilized as the steer's initial and final weights. These weights were used to calculate ADG, feed conversion ratio, and gain to feed ratio.

Feeding, Feed Sampling, and Analysis

All 4 treatment diets were formulated to be approximately 73% TDN and 14% CP on a dry matter basis. Corn silage, whole cottonseed, and cotton gin byproduct were sent to Cumberland Valley Analytic (Waynesboro, PA) for analysis prior to diet formulation. These values can be found in Table 1. The feed composition data received from the analysis of these

three feed ingredients were utilized in diet formulation. These diets were formulated to allow for approximately 1.1 kgs. ADG per NRC (2000) guidelines. Complete diet formulations can be found in Table 2. Treatment 1 served as the control diet and consisted of 75.5% corn silage on a dry matter basis supplemented with ground corn and soybean meal. Treatment 2 contained 75.5% corn silage and 15% whole cottonseed on a dry matter basis supplemented with ground corn and soybean meal. Treatment 3 contained 23% corn silage and 25% cotton gin byproduct on a dry matter basis supplemented with ground corn and soybean meal. Treatment 4 consisted of 23% corn silage, 25% cotton gin byproduct, and 15% whole cottonseed supplemented with ground corn and soybean meal.

The corn silage used in all diets throughout the trial was harvested and stored in silo bags at the NCSU Butner Beef Cattle Field Lab. Silage was utilized from the same silo bag for the entirety of the study. The cotton gin byproduct was donated by Performance Livestock and Feed Co. (Martinsville, VA) in the form of 500 lb. bales. The whole cottonseed was also donated by Performance Livestock and Feed Co. (Martinsville, VA). The whole cottonseed was sourced from Producer's Gin Inc. (Murfreesboro, NC).

Diets were offered to the steers as a total mixed ration (TMR) and were fed once daily. A "slick bunk" feeding strategy was used. The objective of slick bunk management is to match feed delivery as closely as possible to voluntary feed intake. Bunks were cleaned every 2 weeks to remove and weight all orts, or as often as needed if there were significant refusals as determined subjectively by the Nutrition Manager at the Butner Beef Cattle Field Lab. The TMR of each treatment diet was sampled every two weeks and composited monthly for laboratory analysis. Concentrate samples were collected each time feed was mixed. All TMR and concentrate samples were stored in a freezer (-10°C) until they were sent for analysis to Cumberland Valley

Analytical Service (Waynesboro, PA). Feed offering data was collected daily throughout the entirety of the study. Feed offering data and feed refusal data were utilized to calculate feed intake.

Blood Sampling and Analysis

Blood samples were drawn on d 0, 28, 56, and 84 for determination of Blood Urea Nitrogen concentrations (BUN). Blood samples were drawn prior to feeding. Blood was drawn by jugular venipuncture using 10 mL vacutainer tubes containing no additive and 3.81 cm x 20-gauge needles. The blood samples were immediately placed on ice for the duration of sampling and for transport to the laboratory. Serum was obtained by centrifugation at 2,500 x g for 30 minutes and frozen for later analysis. BUN analysis was conducted using the collected serum. The BUN assay was conducted utilizing a microtiter plate method modified for serum from Zawada et al. (2009) and Jung et al. (1975). The reagents used in the assay were those utilized in Zawada et al. (2009); however, a 1:5 dilution factor was utilized for serum samples. This is a colorimetric assay and 96-well plates were read in a Biotek Synergy HT (Winoski, VT) microplate reader at 430 nm.

Economic Analysis

An economic analysis was conducted utilizing the commodity prices found in Table 3. These commodity prices are reflective of the prices experienced during the spring of 2021. Prices utilized for soybean meal, Trace Mineral Salt, Vitamin A, D, and E premix, and Rumensin 90 (Elanco Animal Health, Indianapolis, IN) were the prices paid by the Butner Beef Cattle Field Lab during the trial (T. Cobb, personal communication, May 11, 2021). The corn price utilized

(\$6.37/Bu) was the May 14th, 2021 Conventional County Elevators market price in Shelby, NC (USDA AMS Livestock, Poultry & Grain Market News, 2021). The price utilized for corn silage was calculated using the Petersen Method (Petersen, 1932). The Petersen Method was used to calculate the value of corn silage based on its protein and energy content in comparison to the cost and nutritive value of corn and soybean meal.

The beginning steer value was calculated using a February 18th market price of \$140/cwt for steers averaging 306 kgs. (NC Dept of Ag-USDA Market News Service a, 2021). This price was used to calculate the individual starting value of each steer by multiplying it by their actual start weight. The ending steer value was based on an April 22nd market price of \$129/cwt for steers averaging 413 kgs. (NC Dept of Ag-USDA Market News Service b, 2021). Once again, actual ending weights were used to calculate ending value for each individual steer. The increase in value over the 84-d trial was calculated by subtracting the starting value from the ending value for each steer. To calculate return over feed (ROF) cost, total feed cost was subtracted from the steers' increase in value.

Due to the unprecedented price fluctuations experienced in the past year, an additional analysis was performed utilizing historic commodity prices. The historic commodity prices for corn and soybean meal were 20-year averages from marketing year 1999 to marketing year 2018. These prices were accessed through the USDA Economic Research Service Feed Grains Custom Query (ERS, 2021). Historic No. 2 yellow corn prices were calculated from prices reported in the Memphis, TN area. The Memphis, TN commodity data was utilized as it was the only reporting station in the Southeast United States and the nearest reporting station to North Carolina (USDA-ERS, 2021). Historic soybean meal prices were calculated based on prices reported from Central, IL. The Central, IL region was the only region with soybean meal commodity pricing available

(ERS, 2021). Historic whole cottonseed price was a 15-year average utilizing data from marketing years 2005-2019. This data was accessed via Cotton Incorporated's Cottonseed Market Prices Archives, only the previous 15 years were archived (Cotton Inc., 2021). There is no market data available for cotton gin byproduct since it is not a commodity. The historic price used for cotton gin byproduct was based off personal communication the researcher had with North Carolina cattle producers feeding cotton gin byproduct as well as North Carolina cotton gin operators. These prices can be found in Table 4.

Statistical Analysis

Feed intake and performance data were analyzed using the PROC GLM procedure of SAS (SAS Institute Inc. Cary, NC). Class variables were steer ID, pen, and treatment. Pen effects were not significant therefore, only treatment effects are reported. BUN data were analyzed using a PROC GLM repeated measures analysis in SAS (SAS Institute Inc. Cary, NC). Class variables were steer, diet, and time with testing term of steer within diet. Economic analysis data were analyzed using the PROC GLM procedure of SAS (SAS Institute Inc. Cary, NC). Significance was defined as $P \leq 0.05$.

Results

Feed Composition

The corn silage used in all treatment diets contained 9.0% CP and 70.7% TDN. The whole cottonseed used in this trial contained 25.2% CP and 17.9% crude fat (CF). The cotton gin byproduct contained 13.3% CP and 4.5% CF. All treatment diets were similar in % CP ($13.4 \pm 0.22\%$) (Table 5). Total digestible nutrient values were not calculated for whole cottonseed or

cotton gin byproduct by Cumberland Valley Analytical Service (Waynesboro, PA). Total digestible nutrient values for diet TMRs varied between treatments and were less than estimated 73% for all diets ($68.23 \pm 1.33\%$).

Steer Performance

Dry matter intake did not differ between the control (TRT 1) and whole cottonseed diet (TRT 2), $P > 0.5$. Dry matter intake was highest for the gin byproduct diet (TRT 3) followed by the combination diet containing whole cottonseed and gin byproduct (TRT 4). Both of these diets had higher dry matter intakes than the control (TRT 1) or the whole cottonseed diet (TRT 2) (Figure 1).

Average daily gain was greatest for the cotton gin byproduct diet (TRT 3), 1.5 ± 0.05 kgs. Average daily gains of steers on the control diet (TRT 1, 1.3 ± 0.05 kgs.), the whole cottonseed diet (TRT 2, 1.2 ± 0.05 kgs.), and the combination diet (TRT 4, 1.3 ± 0.05 kgs) did not differ, $P > 0.1$. Average daily gain data is summarized in Figure 2.

The feed conversion ratios of the control diet (TRT 1) and whole cottonseed diet (TRT 2) do not differ, 6.8 ± 0.52 and 6.8 ± 0.52 , respectively ($P > 0.95$). The feed conversion ratio of the cotton gin byproduct diet (TRT 3) and the combination diet (TRT 4) did not differ. Treatment 3 had a higher feed conversion ratio than both TRT 1 and TRT 2 ($P > 0.01$). These results are summarized in Figure 3.

Blood Urea Nitrogen

Blood urea nitrogen intra-assay CV% was 2.6 and inter-assay CV% was 2.9. Treatment 1 had lower BUN (3.4 ± 0.1 mM) when compared to the other three treatments (Figure 4). When

comparing the mean BUN concentrations of d 0, 28, 56, and 84 a polynomial regression can be observed (Figure 5). This regression along with a comparison of treatment*time (Figure 6) show that BUN increased over the course of the trial in all diets, including the control. On d 0 BUN concentrations did not differ between treatments, as expected. Day 28 BUN concentrations were the lowest for TRT 1 (2.77 ± 0.28 mM) when compared to the other three treatments which did not differ. Day 56 BUN concentrations did not differ between TRT 1 (4.24 ± 0.28 mM) and TRT 4 (4.51 ± 0.28 mM). Treatment 2 (5.47 ± 0.28 mM) and TRT 3 (5.08 ± 0.28 mM) did not differ from each other, but were higher than TRT 1 and TRT 4. Treatments 2 (5.91 ± 0.28 mM) and 3 (6.03 ± 0.28 mM) did not differ on d 84, but did differ from TRT 1 (5.10 ± 0.28 mM) and TRT 4 (5.23 ± 0.28 mM) which did not differ.

Economic Analysis

Utilizing current prices, cost per kg. of gain was $\$2.16 \pm 0.07$ for TRT 1, TRT 2, and TRT 3. The cost per kg. of gain for steers in TRT 4 was $\$2.09 \pm 0.07$. There was no difference between treatments for cost per kg. of gain. There were no differences in ROF between treatments. The ROF and cost/kg. of gain are summarized in Table 6.

Utilizing historic prices, cost per kg. of gain was the least for TRT 1 and TRT 3 ($\$1.17 \pm 0.04$ and $\$1.21 \pm 0.04$), respectively; $P > 0.5$. The other treatments, TRT 2 ($\$1.32 \pm 0.04$) and TRT 4 ($\1.45 ± 0.04), differ from one another and from TRT 1 and TRT 3. Return over feed cost was greatest for TRT 1 ($\$112.64 \pm 10.4$) and TRT 3 ($\142.21 ± 10.4), which did not differ ($P > 0.0501$). Return over feed cost did not differ between TRT 2 and TRT 4 ($\$81.08 \pm 10.4$ and $\$84.37 \pm 10.4$), respectively; $P > 0.8$. These results are summarized in Table 7.

Discussion

Feed Composition

The protein content of the corn silage utilized in this study (Table 1) was marginally higher than what is reported in the NRC (2001). The NRC reports corn silage to have 8.7% CP. Additionally, a study by Euken (2018) found the average CP content of corn silage was 6.84%. According to the Dairy One (Ithaca, NY) Interactive Feed Composition Library, the average CP of corn silage samples is 8.2%. The crude protein composition of the whole cottonseed used in this trial (25.2% CP) was slightly greater than the value reported by the NRC (22.0% CP) (2001).

Lalor et al. (1975) suggests that crude protein is the second most variable component of gin byproduct, behind ash content. The cotton gin byproduct used in this trial had a CP value of 13.3%, this is greater than NRC (2001) reported value of 7% and the values reported by Kennedy and Rankins (2008). However, the CP value of the gin byproduct used in this study is within the range of CP values reported by Stewart et al. (1998). The CP value of gin byproduct is dependent upon the weather conditions during the growing season and the amount of whole cottonseed and gin mote remaining in the gin byproduct (Lalor et al., 1975).

Ash content is typically the most variable component of gin byproduct (Lalor et al., 1975). The ash content of the gin byproduct utilized in this trial was 10.2%. This amount is consistent with the NRC (2000) reported value of 10%. Additionally, Stewart et al. (1998) analyzed samples from 38 cotton gins in Georgia and found 11.1% to be the average ash content. The acid detergent fiber (ADF) of the gin byproduct in this trial was 33.5% and the neutral detergent fiber (NDF) was 42.9%. The values observed in this study are less than the average ADF value of 51.5% and NDF value of 60.5% reported by the Dairy One (Ithaca, NY)

Interactive Feed Composition Library. The ADF and NDF values reported by Kennedy and Rankins (2008) were 60.8% and 69.2% respectively.

Although diets were formulated to have the same nutrient value, the TDN values observed from TMR analysis indicated there were differences. Treatment 1, the control, and TRT 3, the cotton gin byproduct diet, had a 6% difference in TDN. While TRT 2 and TRT 4 had similar TDN values. It is important to note that TDN is not measured by an analytic procedure, but is a calculation based on a feed's organic nutrients and digestion coefficient. Cumberland Valley Analytical Services (Waynesboro, PA) does not provide TDN values for byproduct feedstuffs. This could have affected the TDN calculations reported for the TMRs utilized in this study. In formulating treatment diets, the TDN value estimated for cotton gin byproduct was 50%. It is likely that the actual TDN of the gin product used was less than this estimate resulting in TDN values that did not meet our target of 73%.

Animal Performance

Treatment 3, the cotton gin byproduct diet, had the highest DMI followed by TRT 4, the combination diet. These two treatments had greater DMI than TRT 1 and 2 which did not differ. Based on these results, it can be inferred that the addition of cotton gin byproduct stimulated DMI. Kennedy and Rankins (2008) reported increased DMI and increased ADG in steers consuming cotton gin byproduct when compared to steers consuming a peanut hull supplement. Warner et al. (2020) reported increased DMI and ADG for finishing steers consuming a cotton byproduct diet containing cotton gin byproduct, whole cottonseed, and rolled corn than those consuming a control diet of prairie hay, Sweet Bran, rolled corn, and a corn steep and molasses-based liquid fat supplement.

Animal intake is driven by both neural and hormonal control systems (Bell, 1971; Booth et al., 1976; de Jong, 1986). The increased DMI in cotton gin byproduct containing diets could be explained by the lower TDN value of these diets. Steers could have been consuming more feed in order to compensate for lower energy values. However, TRT 2 had a similar TDN value to TRT 4 and did not experience increased DMI. Warner et al. (2020) suggested that the higher DMI observed in steers consuming cotton gin byproduct was a result of higher levels of physically effective neutral detergent fiber (peNDF). Physically effective neutral detergent fiber was not analyzed in this study. Additionally, increases in NDF are often associated with a decline in voluntary intake (Arelovich et al., 2008). Although TRT 3 and TRT 4 had higher amounts of NDF than the control diet (TRT 1), they had the highest DMI. These results are contradictory to the current understanding of feed intake as it relates to the fiber content of the diet. Treatment 3 also had the highest ADG compared to the other three diets that did not differ. This is likely due to the increase in DMI observed, especially given reduced feed conversion on that diet.

When comparing the values recorded for ADG, DMI, and feed conversion ratios the results from TRT 1 and TRT 2 do not differ. This demonstrates that whole cottonseed can replace a portion of the soybean meal and corn utilized in cattle diets without a difference in performance. A study in Georgia demonstrated that lactating cows consuming average quality bermudagrass hay supplemented with 2.1 kgs. of whole cottonseed had equal rates of gain when compared to those supplemented with 1.8 kgs. of corn and 0.7 kgs. of soybean meal (Stewart and Rossi, 2010). This may be advantageous in times where whole cottonseed is priced low relative to soybean meal and corn. To determine if whole cottonseed is priced low in comparison to soybean meal and corn, cost should be determined per unit of nutrient. Determining if cotton gin

byproduct is more economical than other roughage sources can be more complicated. This is due to the increase in dry matter intake experienced when feeding cotton gin byproduct.

Blood Urea Nitrogen

Blood urea nitrogen is commonly used to measure the protein status of ruminants (Hammond, 1983). Blood urea nitrogen analyses may be carried out using serum, plasma, or whole blood (Hammond, 1983). Plasma and serum urea nitrogen assays generally report similar values (Hammond, 1983). Excess nitrogen relative to energy in the rumen increases rumen ammonia content. Unutilized ammonia enters the blood stream and is detoxified in the liver, resulting in urea (Hammond, 1998). The urea can be recycled back to the rumen through the saliva, diffuse back to the rumen via the blood stream, or be excreted in the urine (Hammond, 1983). Blood urea nitrogen concentrations less than 1.16 mM indicate a deficiency of dietary protein in healthy beef cows or finishing cattle and concentrations less than 2.50 mM indicate a deficiency in rapidly growing cattle (Hammond, 1998).

Optimal levels of plasma urea nitrogen in beef cattle were reported to be between 1.83 and 2.5 mM for growing steers (Byers and Moxon, 1980). The levels observed in this trial exceed this range. The d 0 average was 1.78 ± 0.14 mM and by d 84 the serum urea concentration was 5.57 ± 0.14 mM. When comparing overall average BUN concentrations for each treatment, TRT 1 had lower concentrations than all other treatments (3.4 ± 0.14). When comparing all other performance data (Table 8), TRT 1 and TRT 2 did not differ except BUN concentrations.

Blood urea nitrogen concentrations generally increase some with time on feed even without a change in diet (Ruppanner et al., 1978). In the case of this trial, a significant increase

over time was observed in all diets. There are three main diet characteristics that influence blood urea nitrogen concentrations. These are: nitrogen degradability of the diet, energy content, and level of feeding (Hammond, 1983). In this trial level of feeding likely attributed to the increase observed in BUN concentrations. Dry matter intake increased as the cattle increased in BW, this resulted in higher total protein consumption. Additionally, DMI exceeded 3% for steers consuming TRT 3, this was greater than the predicted DMI of 2.5%. Diets were not reformulated to account for the reduction in diet nutrient density needed by steers due to their maturation; therefore, steers were consuming increasing kgs. of CP as DMI intake increased over the 84-d trial. The increase in BUN concentrations observed in TRT 1, the control diet, over time can be partially explained by the change from the acclimation diet to the control diet. For 4 weeks prior to the start of the study steers were only fed corn silage.

The CP content of these diets were in line with NRC (2000) nutrient requirements for growing yearlings weighing 299 kgs., gaining 1.4 kgs., and finishing at approximately 545 kgs. However, the high BUN concentrations observed in this study suggest steers were provided with an excess of nitrogen (CP) in the diet. Only 5-30% of fed nitrogen is utilized by the animal and the rest is excreted (Kohn et al., 2005). Blood urea nitrogen concentrations are highly correlated with urinary nitrogen excretion (Kohn et al., 2005). Not only is providing excess dietary protein cost prohibitive it also may result in negative environmental impacts due to excess nitrogen excretion. However, this demonstrated that cotton byproducts were able to meet and exceed animal protein requirements.

Summary

This study has further confirmed that cotton byproducts are valuable feed resources. Whole cottonseed can be used to replace part of ground corn and soybean meal in the diets of growing steers with no adverse impacts to animal performance. This may be economically advantageous for cattle producers living in cotton producing regions when the price of corn and soybean meal exceed that of whole cottonseed. Additionally, cotton gin byproduct has been shown to increase DMI and ADG. Both whole cottonseed and cotton gin byproduct have been proven to provide adequate protein to the diets of beef steers. Based on the results of this study, producers in cotton producing regions should explore these byproducts as viable additions to their feed program.

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Tables and Figures

Table 1. Chemical composition¹ of feed ingredients used in treatment diets

Nutrient (% DM)	Corn Silage	Whole Cottonseed	Cotton Gin Byproduct
Dry Matter	42.85	88.35	86.75
Crude Protein	9.0	25.2	13.3
Soluble Protein	5.15	11.7	3.95
ADF	21.25	39.3	33.5
aNDF	39.1	47.95	42.85
TDN	70.65	--	--
Crude Fat	--	17.9	4.54
Ash	4.56	5.01	10.2
NE _g	0.53	--	--
ME (Mcal/lb.)	1.23	--	--
Calcium	0.2	0.26	0.85
Phosphorus	0.28	0.67	0.32
Magnesium	0.28	0.46	0.27
Potassium	0.8	1.33	1.44
Sodium	0.01	0.007	0.04
Iron (ppm)	205	77	429
Manganese (ppm)	36	26	56
Zinc (ppm)	43.5	53.5	50
Copper (ppm)	7	13	9

¹Lab analysis conducted by Cumberland Valley Analytical Services, Inc. (Waynesboro, PA).

Table 2. Diet formulation¹ of TMRs

Ingredient	%DM ²	%CP ²	%TDN ²	% of diet DM			
				Control Diet	Cottonseed Diet	Gin Byproduct Diet	Cottonseed + Gin Byproduct Diet
Corn Silage	40.0	10.6	70.1	75.50	75.50	23.00	23.00
Cotton Gin Byproduct	86.0	14.3	50.0	--	--	25.00	25.00
Whole Cottonseed	89.0	22.1	87.0	--	15.00	--	15.00
Ground Corn	90.0	9.0	87.0	14.4	3.70	43.40	32.60
Soybean Meal	90.0	54.0	87.0	8.80	4.50	7.70	3.30
Trace Mineral Salt	--	--	--	0.30	0.30	0.30	0.30
Limestone	--	--	--	1.00	1.00	0.60	0.80

¹A vitamin A, D, and E premix was added at a rate of 823.6 grams/ton. Rumensin 90 was added at a rate of 473.6 grams/ton.

²Estimated composition used for diet formulation

Table 3. Current commodity prices utilized in economic analysis

Feed Ingredient	Cost
Corn ¹	6.37/bushel
Soybean Meal ²	550.00/ton
Corn Silage ³	98.00/ton
Whole Cottonseed ⁴	260.00/ton
Cotton Gin Byproduct ⁴	100.00/ton
Trace Mineral Salt ²	420.00/ton
Vitamin A, D, & E ²	69.00/50 lb.
Rumensin 90 ²	731.00/50 lb.

¹USDA AMS Livestock, Poultry & Grain Market News

²Butner Beef Cattle Field Lab, Bahama, NC

³Calculated using Petersen Method

⁴Performance Livestock and Feed Co., Martinsville, VA

Table 4. Historic commodity prices utilized in economic analysis

Feed Ingredient	Cost
Corn	3.50/bushel
Soybean Meal	300.00/ton
Corn Silage	50.00/ton
Whole Cottonseed	175.00/ton
Cotton Gin Byproduct	50/ton
Trace Mineral Salt	420/ton
Vitamin A, D, & E	69.00/50 lb.
Rumensin 90	731.00/50 lb.

Table 5. Chemical composition¹ of TMRs

Nutrient (% DM)	TRT 1 Control	TRT 2 WCS	TRT3 CGB	TRT 4 WCS & CGB
Dry Matter	46.60	47.05	67.05	69.15
Crude Protein	12.95	13.60	13.15	13.95
Soluble Protein	4.95	5.95	3.90	4.05
ADF	19.05	27.25	33.5	31.1
aNDF	34.45	44.3	42.85	41.00
Ash	5.85	7.10	6.02	6.92
TDN	71.75	68.5	65.45	67.20
NE _g	0.54	0.49	0.44	0.47
ME (Mcal/lb.)	1.25	1.18	1.12	1.13
Calcium	0.68	0.51	0.60	0.71
Phosphorus	0.32	0.41	0.33	0.38
Magnesium	0.25	0.34	0.23	0.26
Potassium	0.875	1.00	1.00	0.98
Sodium	0.13	0.15	0.12	0.15
Iron (ppm)	258.50	285.00	294.5	282.5
Manganese (ppm)	75.00	70.00	67.00	66.00
Zinc (ppm)	103.00	105.50	104.50	100.50
Copper (ppm)	23.00	23.00	22.00	20.5

¹Lab analysis conducted by Cumberland Valley Analytical Services, Inc. (Waynesboro, PA).

Table 6. Results of economic analysis using current commodity prices

	Cost/kg. DM (\$)	Return Over Feed Cost (\$)	Cost per kg. of gain (\$)
Control Diet	0.31	5.56	2.16
Cottonseed Diet	0.29	-3.13	2.16
Gin Byproduct Diet	0.29	20.15	2.16
Cottonseed + Gin Byproduct Diet	0.26	15.58	2.09

¹Means did not differ

Table 7. Results of economic analysis utilizing historic commodity prices

	Cost/kg. DM ¹ (\$)	Return over feed cost ² (\$)	Cost per lb. of gain ³ (\$)
Control Diet	0.18	112.64 ^a	1.14 ^a
Cottonseed Diet	0.18	81.08 ^b	1.32 ^b
Gin Byproduct Diet	0.15	142.2 ^a	1.21 ^a
Cottonseed + Gin Byproduct Diet	0.18	84.37 ^b	1.45 ^c

^{abc} Means with different subscripts differ

¹SEM = 0.75

²SEM = 10.4

³SEM = 0.0

Table 8. Summary of treatment effects on performance data

	Beginning BW kg ¹	Ending BW kg ²	DMI kg ³	ADG kg ⁴	FCR ⁵
Control Diet	290	398	8.86 ^a	1.29 ^a	6.76 ^a
Cottonseed Diet	288	386	8.52 ^a	1.17 ^a	6.81 ^a
Gin Byproduct Diet	285	414	11.31 ^b	1.53 ^b	8.65 ^b
Cottonseed + Gin Byproduct Diet	298	399	10.23 ^c	1.32 ^a	8.24 ^c

^{abc} Means with different subscripts differ

¹SEM=1.09

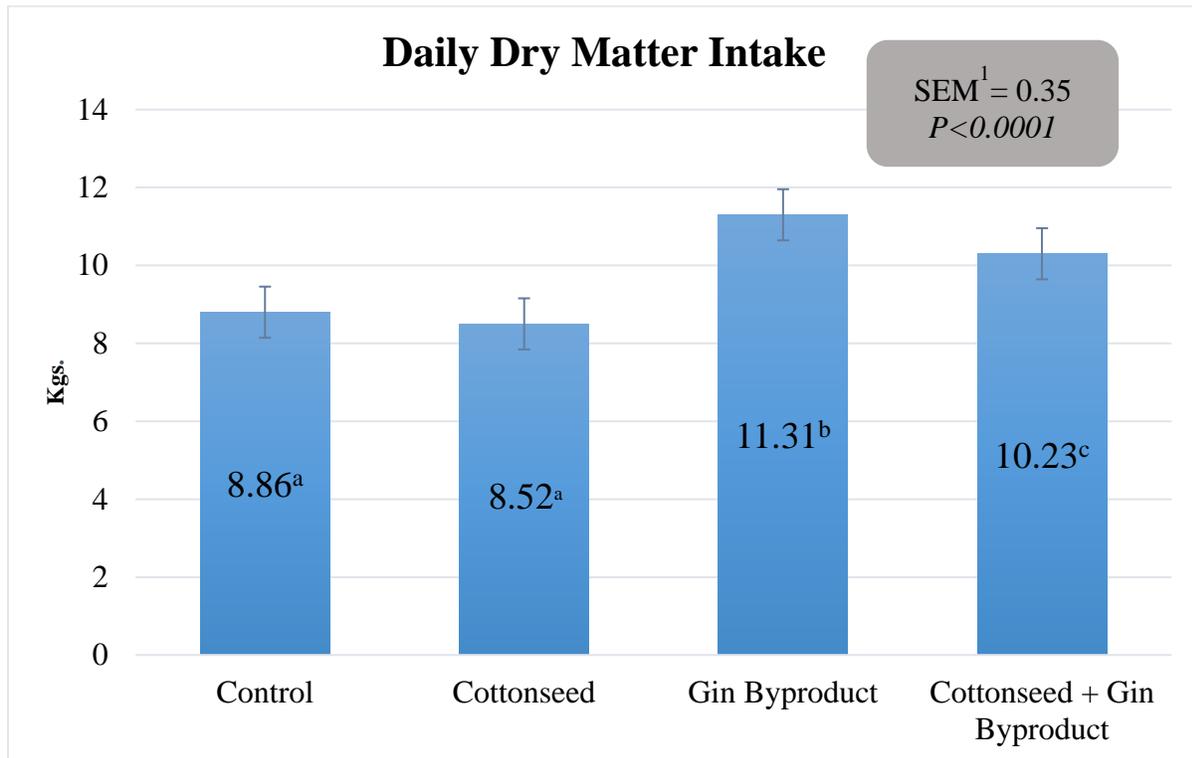
²SEM = 5.58

³SEM=0.35

⁴SEM=0.05

⁵SEM=0.52

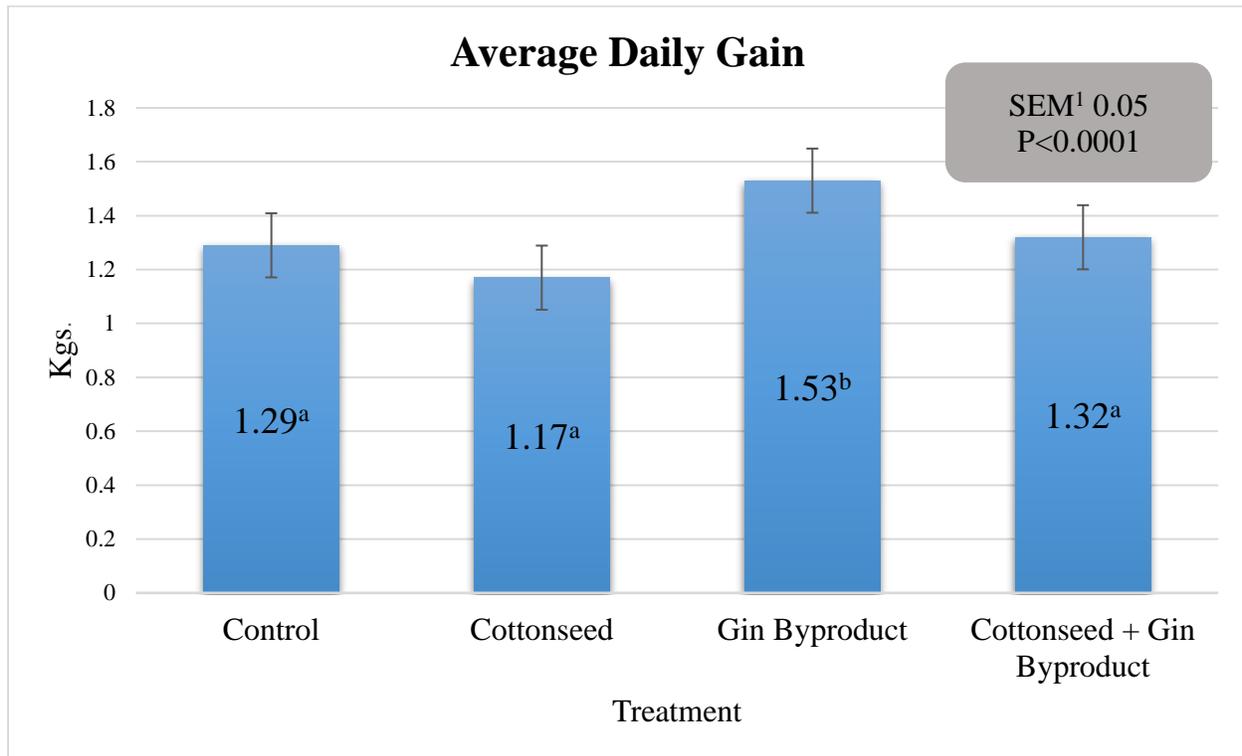
Figure 1. Least squares mean dry matter intake



^{abc} Means with different subscripts differ ($P \leq 0.05$)

¹ Standard error of the mean

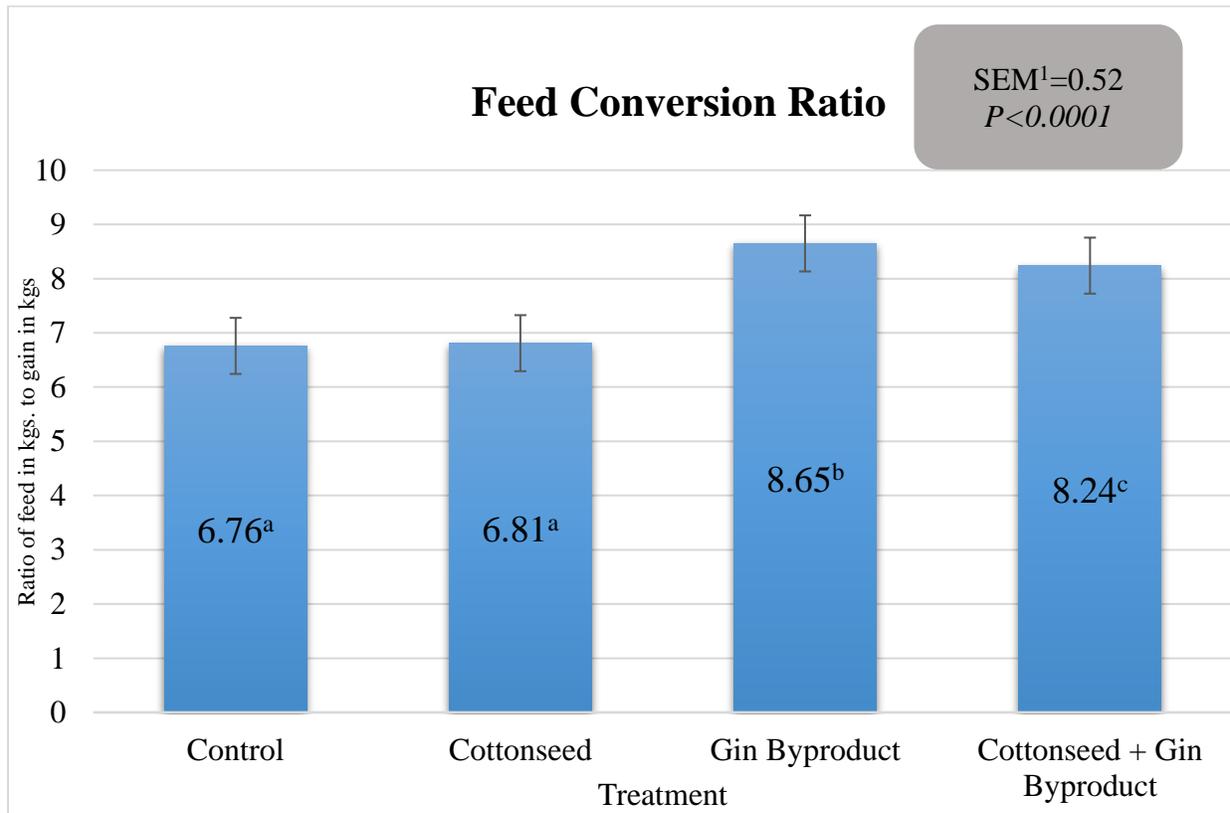
Figure 2. Average daily gain least squares mean per treatment



^{abc} Means with different subscripts differ ($P \leq 0.05$)

¹ Standard error of the mean

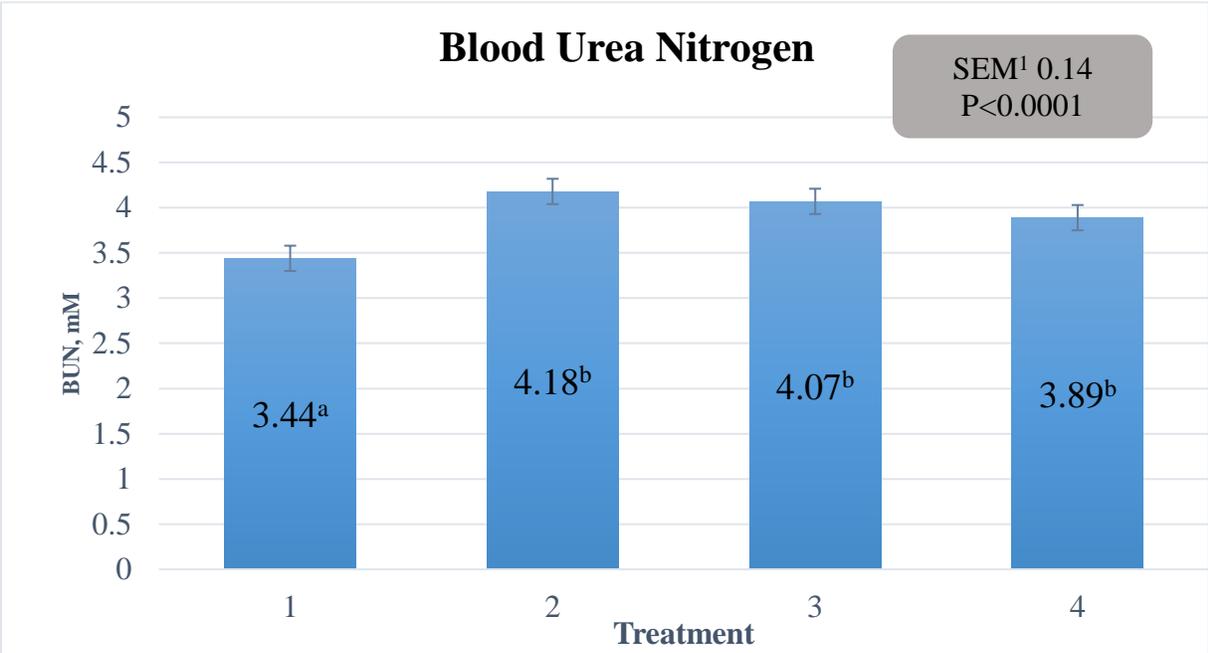
Figure 3. Least squares mean feed to gain ratios for each treatment



^{abc}Means with different subscripts differ ($P \leq 0.05$)

¹ Standard error of the mean

Figure 4: Blood urea nitrogen least squares mean concentrations for each treatment



^{abc}Means with different subscripts differ ($P \leq 0.05$)

¹ Standard error of the mean

Figure 5. Blood urea nitrogen least squares mean concentrations per treatment over time

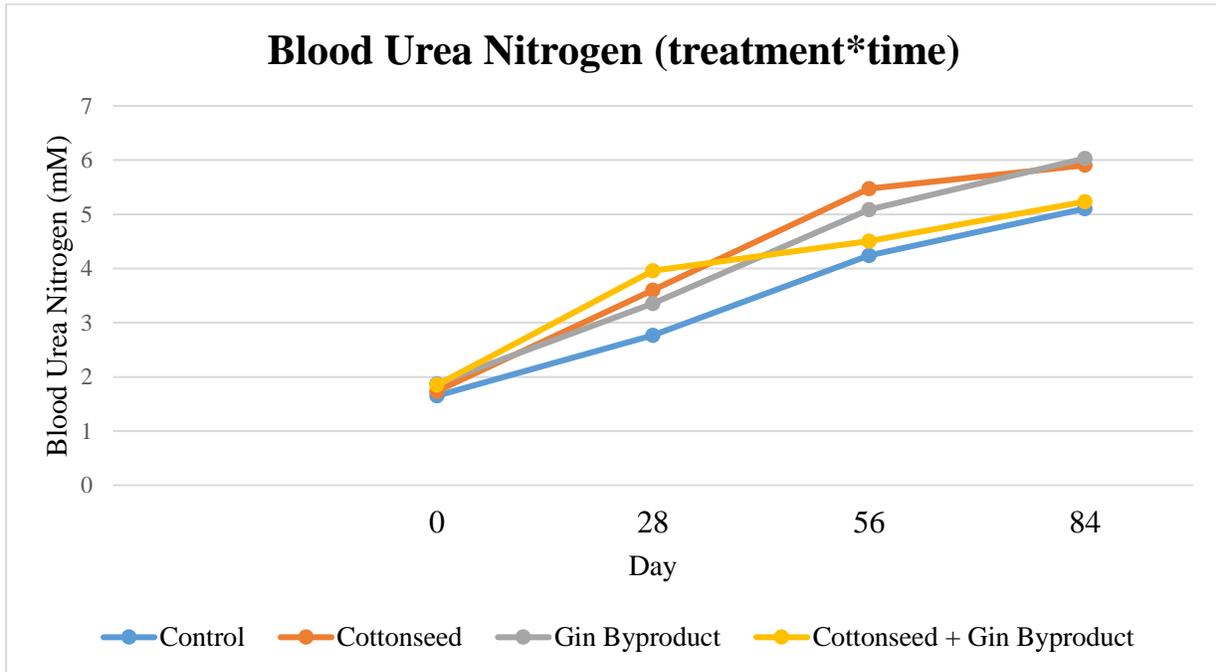
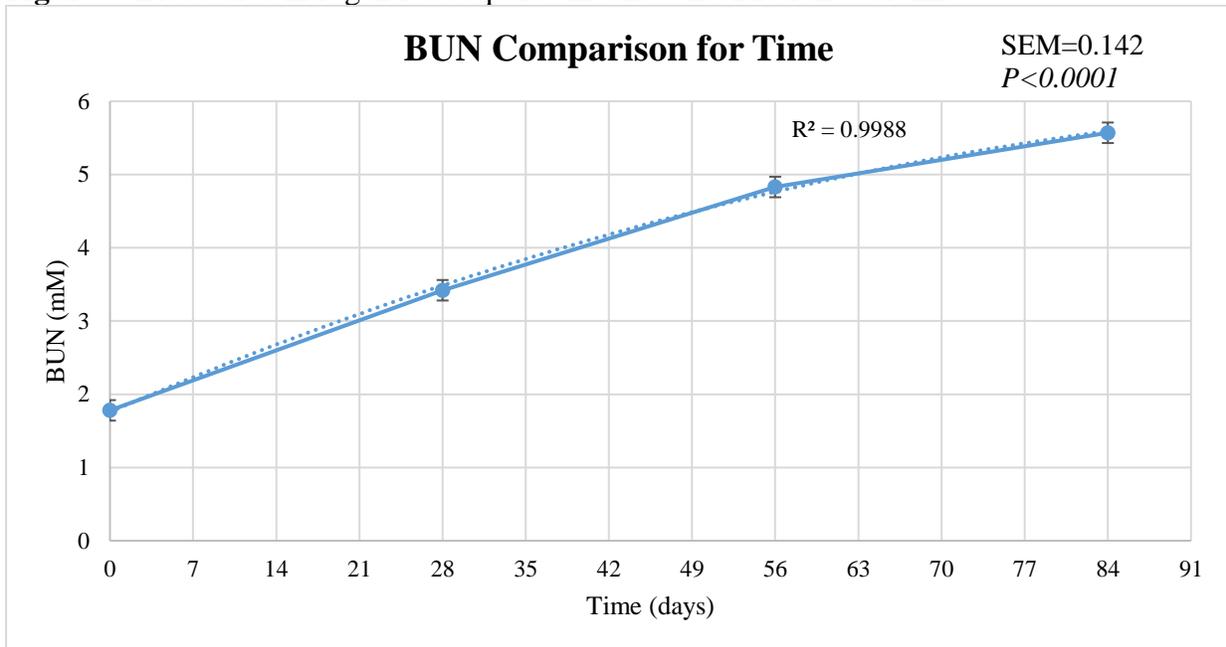


Figure 6. Blood urea nitrogen least squares means concentration over time



CHAPTER 4: COTTON BYPRODUCTS EXTENSION PUBLICATIONS

Utilizing Whole Cottonseed in Beef Cattle Diets

Introduction

In the Southeastern and Southwestern regions of the USA, cotton byproducts are readily available and often underutilized. In 2018, North Carolina alone harvested 415,000 acres of cotton with an average yield of 812 pounds per acre. Seventeen states produce cotton in the United States. Production information for these states can be found in Table 1. Approximately 675 pounds of cottonseed are produced for every single 480-pound bale of fiber. After cotton is harvested, it is ginned. This process separates the lint, or cotton fiber, from debris and cottonseed. This whole cottonseed can be directly used as a feed supplement or can be further processed. For most cattle enterprises, the largest expense is feed. Byproduct feeds can play an important role in creating a cost-effective feed ration. Whole cottonseed can serve as an economical source of protein, fat, and fiber compared to traditional feeds in beef cattle diets.

Nutrient Composition

Whole cottonseed is an excellent source of protein, fiber, energy, fat, and phosphorus. The high energy value, or TDN (Total Digestible Nutrients), of whole cottonseed is due to the high oil content of the seed. It is important to note that the values found in Table 2 are known values or typical averages. The nutrient content of cottonseed may vary depending on cotton variety, storage, and handling. To accurately determine the nutritive value of the available source of cottonseed, a feed analysis should be conducted.

Feeding Guidelines

Whole cottonseed is unique because it supplies high levels of energy, protein, and fiber to the diet. This makes it an exceptional supplement to both poor-quality hay and stockpiled pastures. The high-fat value of whole cottonseed has also been shown to improve reproductive efficiency in cows. However, this high-fat content is also the limiting factor in adding it to beef cattle diets. To allow the rumen to function properly and avoid scouring, added fat in the diet should not exceed 4%. Because of this, it is recommended that the maximum amount fed should not exceed 0.33% of body weight for weaned calves and 0.5% of body weight for mature cows. Whole cottonseed should not be fed to young, nursing calves. When feeding cow-calf pairs, small calves may eat some whole cottonseed, but consumption rates will be low and generally not of concern.

When used in a mixed ration for growing cattle, whole cottonseed should not exceed 15% of the total ration dry matter. This includes dry matter from hay and pasture. Because whole cottonseed is high in phosphorus but low in calcium, cattle should also have access to a high-calcium mineral supplement.

Whole cottonseed presents a unique handling and storage challenge as the seeds do not flow well through grain bins and augers. Cottonseed handles best with a front-end loader, silage fork, buckets, or bags. Whole cottonseed can be fed from a feed wagon, or by hand, with the seed placed in a trough or on clean sod under a temporary electric fence. Some producers who choose to unroll their hay may find that placing piles of whole cottonseed on the hay works well.

Whole cottonseed is less palatable than many other feeds. Cattle unfamiliar with it may need to be trained to eat whole cottonseed by top dressing it with a more palatable feed. Cows

supplemented with whole cottonseed during the winter will likely stop eating the cottonseed once spring grass begins to grow.

A Word About Gossypol

Gossypol is a natural toxin found in the cotton plant. This toxin helps to protect the plant from insects. The gossypol toxin is most concentrated in the seed. Gossypol negatively affects non-ruminant animals like pigs and poultry who cannot tolerate the toxin. Ruminants, like cattle, are not as severely affected by gossypol when cottonseed is fed at moderate levels after they have developed a rumen. Small calves typically do not eat much cottonseed when it is being fed to their mothers, however, cottonseed should not be fed to young calves as part of a concentrate or total mixed ration.

It is known that gossypol, at a high level, can cause a temporary reduction in fertility of bulls. For this reason, we recommend feeding a maximum of 0.33% of body weight for growing bulls and 0.5% of body weight for mature bulls. As a precaution, bulls should not be fed whole cottonseed 60 to 90 days before the start of the breeding season. As long as feeding guidelines are followed, gossypol toxicity should not cause problems after bulls are with cows being supplemented with cottonseed.

Do not feed more than the recommendation, even if cottonseed is very inexpensive. In general, if you follow feeding guidelines there should be no problems with gossypol when feeding whole cottonseed to cattle.

Purchasing and Storage Considerations

Whole cottonseed can be purchased directly from cotton gins during the ginning season, as it leaves the gin. This is often at a lower price than buying the cottonseed later, from storage. Whole cottonseed can also be purchased from a commodity broker in tractor-trailer loads. Many dairy farms rely on whole cottonseed as a portion of their total mixed ration. Small farms that are near a dairy may be able to take advantage of this by purchasing a smaller quantity of whole cottonseed directly from the dairy. Also, for producers needing a smaller quantity, it may be useful for several producers to go in together and purchase a truckload to be split amongst them.

Whole cottonseed must be stored in a manner that will keep it dry. Excess moisture not only poses a safety risk but also diminishes the nutritive value of the feed. If cottonseed is stored too wet or stacked too high, it could generate heat and possibly even spontaneously combust. For this reason, it is recommended that wet cottonseed should not be placed in storage, and it should be kept dry while in storage. In addition to heat damaging the seed, excess heat and moisture will cause a mold issue. Mold mycotoxins like aflatoxins could pose an issue for animal health. Sometimes heat-damaged whole cottonseed is available at a low price, but producers should sample and test the seed to determine its potential feeding value.

It is not recommended to store whole cottonseed in grain bins, since it does not flow well through an auger system. Whole cottonseed should be stored under a shelter that has good ventilation and protects it from rain. Storing whole cottonseed on a dirt floor or a layer of plastic could cause the whole cottonseed to sweat and accumulate moisture. When storing in an open dirt-floored shed use a layer of straw or hay before piling the cottonseed. When using a small quantity of whole cottonseed, it can be stored in a wagon, dump truck, or bags. For large producers a commodity shed with a concrete floor is the ideal storage area.

Summary

Whole cottonseed can be a useful energy, protein, and fat supplement to cattle at various stages in the production cycle. Feeding cottonseed can require increased management as special considerations must be made for storage and handling. When recommended guidelines are followed, no adverse effects are noted.

Tables and Figures

Table 1. Production Overview of Cotton Producing States ^a

State	Acres Harvested	Yield (lbs./acre)	Production (480 lb. bales)	Cottonseed Produced ^b (tons)	Cotton Gin Byproduct (tons)
Alabama	497,000	858	888,000	299,700	44,400
Arizona	173,500	1,288	465,500	157,106	23,275
Arkansas	480,000	1,133	1,133,000	382,387	56,650
California	47,000	1,910	187,000	63,113	9,350
Florida	93,000	532	103,000	34,763	5,150
Georgia	1,305,000	719	1,955,000	659,813	97,750
Kansas	152,000	1,077	341,000	115,088	17,050
Louisiana	189,000	1,067	420,000	141,750	21,000
Mississippi	615,000	1,141	1,462,000	493,425	73,100
Missouri	322,000	1,245	835,000	281,813	41,750
New Mexico	62,800	959	125,500	42,356	6,275
North Carolina	415,000	812	702,000	236,925	35,100
Oklahoma	550,000	595	682,000	230,175	34,100
South Carolina	275,000	733	420,000	14,175	21,000
Tennessee	355,000	1,041	770,000	259,875	38,500
Texas	4,350,000	756	6,850,000	2,311,875	342,500
Virginia	97,000	896	181,000	61,088	9,050
TOTAL	9,978,300	986 (Average)	17,520,000	5,785,425	876,000

^aSource: USDA National Agricultural Statistics Service, Cotton County Estimates (2018)

^b Calculated based on the average of 675 lbs. of cottonseed per bale of fiber

^c Calculated based on the average of 100 lbs. of gin byproduct per bale of fiber from picker harvested cotton. It is important to note that this a conservative estimate for states that utilize post picker and stripper harvesters, such as Texas. Stripper harvested cotton averages 350 lbs. of gin byproduct per bale of fiber.

Table 2. Nutrient Composition of Whole Cottonseed, Corn Gluten Feed, and Soybean Hulls on a Dry Matter Basis. ^a

Nutrient	Whole Cottonseed	Corn Gluten Feed	Soybean Hulls
Dry Matter, %	92	89	91
Crude Protein, %	23	23	12
TDN, ^b %	90	80	78
Crude Fat, %	20	3	2
Crude Fiber, %	20	10	40
NDF, ^c %	52	35	67
ADF, ^d %	30	11	50
Calcium, %	0.2	0.10	0.49
Phosphorus, %	0.8	1.01	0.18
NE _m , ^e Mcal/kg	2.24	0.88	0.65
NE _g , ^f Mcal/kg	1.55	0.59	0.45
Pounds per 5 gal	16	22	20
^a Source: NRC (2000), Nutrient Requirements of Beef Cattle, National Research Council, Washington, DC, USA ^b Total digestible nutrients ^c Neutral detergent fiber ^d Acid detergent fiber ^e Net energy for maintenance ^f Net energy for weight gain			

Table 3. Utilizing Production Phase and Bodyweight to Calculate Amount of Whole Cottonseed Per Head Per Day

	Percent of Body Weight	Total Body Weight (lbs)	Whole Cottonseed (lbs/head/day)
Growing Steers or Heifers	0.33%	500	1.7
Growing Steers or Heifers	0.33%	800	2.6
Growing Bull	0.33%	1,200	4
Mature Bull	0.5%	2,000	10
Mature Cow	0.5%	1,200	6
Mature Cow	0.5%	1,500	7.5

Incorporating Gin Byproduct into Cattle Diets

Introduction

In the process of taking cotton from the field to creating a finished product, there are several byproducts created along the way. In cotton-producing regions, these byproducts are often underutilized by cattle producers. After cotton is harvested, it is sent to a cotton gin to remove the seeds and other debris from the fiber. Cotton gin byproduct, commonly called gin trash or cotton burrs, is one of the byproducts created from cotton ginning. It is composed of fragmented leaves, stems, bolls, lint, and even soil. It is aptly referred to as gin “trash” by cotton gins because it provides gins with little to no value and often creates a disposal problem. However, cotton gin byproduct can be used as a fiber and energy source in cattle diets.

Nutrient Composition

Although the nutritive value of gin byproduct is typically low, it can be used as an economical roughage source in beef cattle diets. Cotton gin byproduct can vary greatly depending upon the cotton variety, method of harvesting, ginning process, and storage. Because of this variation it is recommended to have a nutrient analysis performed before including gin byproduct in your feeding program. Typical gin byproduct has a similar nutritional value to that of a low to medium quality hay.

Purchasing and Storage

Cotton gin byproduct can be purchased from cotton gins during the ginning season. Cotton gin byproduct has low bulk density, making it difficult to transport. This can be solved by purchasing gin byproduct that has been placed into modules or bales. It is important to note that standard cotton modules are 7.5 feet wide, 32 feet long, and vary between 9 and 11 feet tall. These modules weigh 5-8 tons. It is recommended to plan out where you will be feeding these modules prior to their delivery. Once they are unloaded using a specialized truck, they are very difficult to move. Some gins will place cotton gin byproduct into bales which will be smaller, lighter, and easier to handle (500-800 lbs.). In order to reduce molding, and thus mycotoxins, and to maintain the nutritional quality, it is very important to keep cotton gin byproduct dry. Some cotton gins may wet down the cotton byproduct with water during the ginning process to control dust and to enhance composting, but this is undesirable when using the byproduct for feed. Check with your gin prior to purchasing to ensure you are getting a dry product. If you are not feeding the gin byproduct right away, it needs to be protected from moisture. Cotton module covers or large tarps can be placed over modules to shield from rain. Ideally, bales of cotton gin byproduct should be stored in a hay storage shed. Alternatively, bales could be placed on wooden pallets to lift them off of the ground and be covered with a tarp until feeding to keep them dry and reduce loss. Loose gin byproduct is sometimes used when in close proximity to the gin, and it needs to be stored in open storage and is best used in a mixed ration.

Feeding Recommendations

Cotton gin byproduct can be incorporated into a variety of management systems; however, one of the best usages of gin byproduct is in the feed ration of dry, pregnant cows due

to their lower daily feeding cost. To reap the greatest benefits from cotton gin byproduct, it is best fed along with an additional supplement. Cotton gin byproduct can be used similarly to low quality hay. It can help supplement cattle on stockpiled pastures. Cotton gin byproduct supplemented with whole cottonseed is an excellent way to provide protein and fat to cattle diets.

Cattle may take some time adjusting to consuming gin byproduct, as it is typically unpalatable at first. However, once they start consuming the material intake will increase rapidly and they will eat it aggressively. When feeding modules of cotton gin byproduct, it is recommended to use a single strand of electric wire to restrict access to the module. As the cattle consume the cotton gin byproduct, the wire should be moved back allowing access to more of the module. When fed as bales, cotton gin byproduct can be fed in hay rings or hay trailers. When the material is loose, it is best fed as part of a total mixed ration.

Chemical Residues

Gossypol toxicity is not typically an issue when feeding cotton gin byproduct, but chemical residues can be of concern. Many of the chemicals used in cotton production are not cleared to be used in livestock feedstuffs. Concentrations of these chemicals are typically low and not bioaccumulating. This is most important when feeding cotton gin byproduct in finishing rations. A fourteen-day withdrawal period prior to slaughter is recommended for extra safety.

Summary

Cotton gin byproduct can be an economical roughage source in the diets of beef cattle. There is potential for this product to be used as a winter feed, partial replacement for hay during flooding or drought, and as a roughage source in feedlot cattle diets. Its best use is in maintaining

dry, brood cows through the winter feeding-season with minimal supplementation. Due to its high variability, and nutritive value usually higher than published “book values” a nutrient analysis should be conducted prior to developing a feeding program.

Tables and Figures

Table 1. Nutrient Composition of Gin Byproduct on a Dry Matter Basis. ^a

Nutrient	Gin Byproduct
Dry Matter, %	90
Crude Protein, %	7
TDN, ^b %	44
Crude Fat, %	2
Crude Fiber, %	40
Lignin %	14
ADF, ^c %	46
Calcium, %	0.8
Phosphorus, %	0.2
NE _m , ^d Mcal/kg	0.35
NE _g , ^e Mcal/kg	0.03
^a Source: NRC (2000), Nutrient Requirements of Beef Cattle, National Research Council, Washington, DC, USA ^b Total digestible nutrients ^c Acid detergent fiber ^d Net energy for maintenance ^e Net energy for weight gain	

Utilizing Cottonseed Hulls in Beef Cattle Diets

Introduction

Cottonseed hulls are readily available in areas where cottonseed oil mills are located and are marketed across the country as a commodity feed. After cotton is harvested, it is ginned to remove the cottonseed and debris from the lint or fiber portion. Whole cottonseed can be fed as is or crushed for oil and high-protein meal. Cottonseed hulls are the outer portion of the whole cottonseed and are a byproduct of oil and meal production. While cottonseed hulls are low in nutrients, they can be a palatable source of roughage or fiber in beef cattle rations and are often used in starting feeds for beef cattle and in diets for dairy cattle to stimulate feed intake.

Nutrient Composition

Cottonseed hulls are classified as a roughage feed. The National Research Council classifies a roughage feed as having a minimum crude fiber content of 18% and a maximum content of total digestible nutrients (TDN) of 70%. Note that the values found in Table 1 are known values or typical averages. Nutrient content of cottonseed hulls may vary depending on storage and handling. To accurately determine the nutritive value of the available source of cottonseed hulls a feed analysis should be conducted.

Feeding Recommendations

A unique feature of cottonseed hulls is that they are very palatable to cattle despite their high fiber content. Cottonseed hulls can be added to rations to increase palatability and consumption. Cottonseed hulls can be used as the sole source of fiber or roughage in some cattle

production systems. Cottonseed hulls work well in preconditioning diets due to their palatability and fiber content. The hulls stimulate intake in young cattle who are fed high grain diets. This is one reason that cottonseed hulls are a popular component of show cattle rations and preconditioning/starter feeds. Cottonseed hulls incorporate well into total mixed rations (TMR) and can provide the sole source of roughage in finishing diets. Cottonseed hulls can be used as hay replacement during times of hay shortage in brood cow diets, although their high price may limit this use. Three pounds of cottonseed hulls can replace 2 lbs. of average-quality hay. Cottonseed hulls should not exceed more than 50% of the diet.

Gossypol toxicity is typically not an issue when feeding cottonseed hulls. Gossypol is found at its highest levels in the meat portion of the whole cottonseed. Only trace amounts are found in the hulls. The small amounts that occur are due to a small amount of meat remaining in the hulls. In recent times, cottonseed hulls are priced relatively high to their energy value when compared to other feedstuffs. This makes cottonseed hulls not particularly economical when fed as a large proportion of the diet.

Purchasing and Storage

Cottonseed hulls can be purchased as intact hulls from a cotton oil mill, usually through a commodity broker. The hulls can also be pelletized and purchased from a livestock feed retailer. Pelleted hulls offer ease of handling as they readily flow through normal grain handling augers and bins, whereas loose hulls will not. Cottonseed hulls should be stored under a shelter that has good ventilation and protects it from rain. Similar to whole cottonseed, cottonseed hulls are best stored in a commodity shed. A commodity shed with a concrete floor works best as it will keep

the hulls dry and allow for ventilation. Loose cottonseed hulls are easiest handled with a front-end loader.

Summary

Cottonseed hulls can help to make a diet more palatable, so are most effectively used in show cattle rations, preconditioning feeds, dairy cattle diets, feedlot diets, or whenever there is a need to provide a convenient source of fiber and stimulate feed intake. With a high fiber content, cottonseed hulls can be used as the sole roughage source in growing and finishing diets for beef cattle. Cottonseed hulls also make a good hay substitute in brood cow diets. Gossypol toxicity is generally not a concern when feeding cottonseed hulls. Cottonseed hulls are best stored in a covered area with good ventilation to keep the hulls dry. Due to their high cost relative to their energy value, other feedstuffs may prove to be more economical.

Tables and Figures

Table 1. Nutrient Composition of Cottonseed Hulls on a Dry Matter Basis. ^a

Nutrient	Whole Cottonseed
Dry Matter, %	91
Crude Protein, %	4.1
TDN, ^b %	45
Crude Fat, %	1.7
Crude Fiber, %	47.8
NDF, ^c %	86.9
ADF, ^d %	67
Calcium, %	0.15
Phosphorus, %	0.09
NE _m , ^e Mcal/kg	0.31
NE _g , ^f Mcal/kg	0.07
^a Source: NRC (2000), Nutrient Requirements of Beef Cattle, National Research Council, Washington, DC, USA ^b Total digestible nutrients ^c Neutral detergent fiber ^d Acid detergent fiber ^e Net energy for maintenance ^f Net energy for weight gain	

APPENDICES

APPENDIX A: Census Cover Letter Email

Dear North Carolina Cotton Ginners,

My name is Elizabeth Mullins, and I am a graduate student within the Department of Animal Science at North Carolina State University. For my thesis, I am evaluating the feeding value of whole cottonseed and cotton gin byproducts for growing cattle. As a portion of this project, I am conducting a survey of all of the cotton gins in North Carolina. Specifically, we would like to know more about the current management and marketing of whole cottonseed and cotton gin byproducts (gin trash and mote). Cattle producers across the state are interested in accessing and feeding cottonseed and gin byproducts, yet we have very little information to provide them about the supply chain. It is our hope to eventually be able to create a directory of cotton gins that are willing to sell cotton byproducts locally to cattle producers. If you are interested in being a part of this directory, please include your contact information in the survey.

This survey will be sent to all cotton gins in North Carolina. I received your contact information from the Southeastern Cotton Ginners Association, Inc. directory. Your participation is strictly voluntary. I would greatly appreciate it if you completed this questionnaire. We are asking that one survey be completed per gin. There are no risks associated with your participation. The results of this study have the potential to benefit cotton gins, cotton producers, and cattle producers throughout North Carolina and the Southeast.

Thank you for taking time to assist me in my research and educational endeavors in addition to benefitting the cotton and cattle industries. If you have any questions or comments about this study, please feel free to contact me at the phone number or email listed below.

Sincerely,



Elizabeth Mullins

Graduate Research Assistant, Department of Animal Science

[\(276\) 639-0317](tel:2766390317) | epmullin@ncsu.edu

Polk Hall (Office 208)

Follow this link to the Survey:

[\\${1://SurveyLink?d=Take the Survey}](#)

Or copy and paste the URL below into your internet browser:

[\\${1://SurveyURL}](#)

Follow the link to opt out of future emails:

[\\${1://OptOutLink?d=Click here to unsubscribe}](#)

APPENDIX B: Census

NC STATE UNIVERSITY

Cotton Gin Owner/Manager Consent Form

Title of Study: North Carolina Cotton Gin Survey (20747)

Principal Investigator(s): Elizabeth Mullins, epmullin@ncsu.edu (276) 639-0317

Funding Source: North Carolina Cattlemen's Association

Faculty Point of Contact: Matt Poore, mhpoore@ncsu.edu, (919) 515-7798

What are some general things you should know about research studies?

You are invited to take part in a research study. Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate, and to stop participating at any time without penalty. The purpose of this research study is to gain a better understanding of how cottonseed and cotton gin byproducts are managed and marketed in North Carolina. We will do this by asking your participation in a short online survey.

You are not guaranteed any personal benefits from being in this study. Research studies also may pose risks to those who participate. You may want to participate in this research because it has the opportunity to benefit both cotton gins, cotton farmers, and cattle farmers in North Carolina. You may not want to participate in this research because it is time consuming, although minimally.

Specific details about the research in which you are invited to participate are contained below. If you do not understand something in this form, please ask the researcher for clarification or more information. A copy of this consent form will be provided to you. If, at any time, you have questions about your participation in this research, do not hesitate to contact the researcher(s) named above or the NC State IRB office. The IRB office's contact information is listed in the *What if you have questions about your rights as a research participant?* section of this form.

What is the purpose of this study?

The purpose of the study is to gather information about how cottonseed and cotton gin byproduct are currently being managed and marketed throughout the state. There is much interest in using cottonseed and cotton gin byproducts as cattle feed in North Carolina. However, we currently have little information about the local supply chain of these products.

Am I eligible to be a participant in this study?

There will be approximately 34 participants in this study.

In order to be a participant in this study, you must agree to be in the study, be 18 years of age or older, and be either the owner or manager of a North Carolina cotton gin.

You cannot participate in this study if you do not want to be in the study, if you are under the age of 18, or if you are not an owner or manager of a North Carolina cotton gin.

What will happen if you take part in the study?

If you agree to participate in this study, you will be asked to take an online or written survey taking approximately 7-10 minutes.

The total amount of time that you will be participating in this study is 7-10 minutes.

Risks and benefits

There are minimal risks associated with participation in this research.

There is the potential for your cotton gin to gain direct benefit from your participation in the research if you volunteer your contact information to be added to a directory of cotton gins that will sell cottonseed and cotton gin byproducts locally. The indirect benefits are the potential to develop a better understanding of the supply chain for cottonseed and cotton gin byproducts which will increase the local use of these feeds; benefitting cotton gins, cotton farmers, and cattle farmers.

Right to withdraw your participation

You can stop participating in this study at any time for any reason. In order to stop your participation, please contact Elizabeth Mullins at epmullin@ncsu.edu or (276) 639-0317. You may also contact Matt Poore at mhpoore@ncsu.edu or (919) 515-7798. If you choose to withdraw your consent and to stop participating in this research, you can expect that the researcher(s) will redact your contact information (if provided) from their data set, securely destroy your data, and prevent future uses of your contact information (if provided) and confidential survey for research purposes wherever possible. This is possible in some, but not all, cases.

Confidentiality, personal privacy, and data management

Trust is the foundation of the participant/researcher relationship. Much of that principle of trust is tied to keeping your information private and in the manner that we have described to you in this form. The information that you share with us will be held in confidence to the fullest extent allowed by law.

Protecting your privacy as related to this research is of utmost importance to us.

How we manage, protect, and share your data are the principal ways that we protect your personal privacy. Data generated about you in this study will be confidential. No reference will be made in oral or written reports which could link you to this study.

Identifiable. Identifiable data is information that directly links you to the data. This includes but is not limited to, your name, e-mail, phone number, or other details that make you easily recognizable to us and others. Identifiable data has your real identity directly included with your survey response that will be shared with me. This information is confidential and will not be shared with anyone unless you choose to be included in our cotton gin directory to be shared with North Carolina cattle producers.

Compensation

You will not be compensated for participation in this survey

Sponsorship and Funding

This research is funded by the North Carolina Cattlemen's Association This means that the sponsor is covering the expenses incurred during this research study. The researchers do not, however, have a direct financial interest with the sponsor or in the final results of the study.

What if you have questions about this study?

If you have questions at any time about the study itself or the procedures implemented in this study, you may contact the researcher, Elizabeth Mullins at epmullin@ncsu.edu or (276) 639- 0317. You may also contact her faculty advisor, Matt Poore at mhpoore@ncsu.edu or (919) 515-7798

What if you have questions about this study?

If you have questions at any time about the study itself or the procedures implemented in this study, you may contact the researcher, Elizabeth Mullins at epmullin@ncsu.edu or (276) 639- 0317. You may also contact her faculty advisor, Matt Poore at mhpoore@ncsu.edu or (919) 515-7798

What if you have questions about your rights as a research participant?

If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact the NC State IRB (Institutional Review Board) Office. An IRB office helps participants if they have any issues regarding research activities. You can contact the NC State IRB Office via email at irb-director@ncsu.edu or via phone at (919) 515-8754.

Consent To Participate

By selecting "*I consent, begin the study*", I am affirming that I have read and understand the above information. All of the questions that I had about this research have been answered. I have chosen to participate in this study with the understanding that I may stop participating at any time without penalty or loss of benefits to which I am otherwise entitled. I am aware that I may revoke my consent at any time.

- I consent, begin survey
- I do not consent to this survey



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Contact Information (This will not be shared unless you consent to be added to the cotton gin directory)

Name

E-mail

Gin Name

Gin Address

Address

City

ZIP/Postal Code



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How many 500 lb bales of cotton do you gin in a typical ginning season?



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The following questions pertain to your gin's production of cottonseed.

In a typical year, how much cottonseed is produced at your gin in one ginning season?

Where does the majority of this whole cottonseed go?

- In-state
- Out-of-state

What is the majority of whole cottonseed sold from this gin being used for?

- Crushed for oil
- Livestock feed
- Other

Would you consider selling cottonseed locally as cattle feed?

- Yes
- Maybe
- No
- We already sell cottonseed locally as cattle feed.

If you selected "No" to the previous question, why would you NOT consider selling cottonseed locally as cattle feed?

If you currently sell cottonseed locally, do you arrange shipping?

Yes

No

Other



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The following questions pertain to your gin's production of gin trash.

In a typical year, how much gin trash is produced at your gin in one ginning season?

What is your gin currently doing with its gin trash?

- Stock-piled and allowed to decompose on-site
- Managed composting
- Sold as cattle feed
- Other

If your gin currently markets gin trash as cattle feed, what form is being sold?

- Bales
- Modules
- Loose
- Other

Where does the majority of your gin's gin trash go?

- In-state
 - Out-of-state
 - Nowhere, it stays at the gin.
-

Would you consider selling gin trash locally as cattle feed?

- Yes
 - Maybe
 - No
 - We are already selling gin trash locally as cattle feed.
-

If you would NOT consider selling gin trash as cattle feed, why?

If you currently sell gin trash locally as cattle feed, do you arrange shipping?

- Yes
- No
- Other



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The following questions pertain to your gin's production of gin mote.

Does your gin have a mote press?

- Yes
 - No
 - Other
-

If yes, how does your gin market mote?

- Sold for re-ginning
 - Sold locally as cattle feed
 - Other
-

Would you consider selling gin mote locally as cattle feed?

- Yes
 - Maybe
 - No
 - We already sell gin mote locally as cattle feed.
-

If you sell gin mote locally as livestock feed, do you arrange shipping?

- Yes
- No
- Other



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If you are interested in selling cottonseed and cotton gin byproducts locally, would you like to be added to our cotton gin directory to be provided to North Carolina cattle producers?

- Yes! Please add me to the directory.
- No! Do not add me.
- Other



APPENDIX C: Reminder Email

Hello!

I hope this email finds you healthy and well. This is a reminder to please take the North Carolina Cotton Gin Survey or to finish the survey that you have started! You can take the survey at the link below. This survey is helping us learn more about what cotton byproducts are used for in North Carolina. Additionally, without taking this survey your gin will not be included in the directory we are creating for cotton gins who wish to market their cotton byproducts locally as livestock feed. I will be following up by telephone with cotton gins who have not responded starting next Monday, April 27th. Please feel free to reach out to me with any questions or concerns.

Best Regards,



Elizabeth Mullins

Graduate Research Assistant, Department of Animal Science

(276) 639-0317 | epmullin@ncsu.edu

Polk Hall (Office 208)

Follow this link to the Survey:

[\\${1://SurveyLink?d=Take the Survey}](#)

Or copy and paste the URL below into your internet browser:

[\\${1://SurveyURL}](#)

Follow the link to opt out of future emails:

[\\${1://OptOutLink?d=Click here to unsubscribe}](#)