

EVALUATION OF COTTON GIN TRASH AS A ROUGHAGE SOURCE FOR
STOCKER CATTLE

Except where reference is made to the work of others, the work described in this thesis is my own or was done in collaboration with my advisory committee. This thesis does not include proprietary or classified information.

Julie Blair Kennedy

Certificate of Approval:

Russell B. Muntifering
Professor
Animal Sciences

Darrell L. Rankins, Jr., Chair
Professor
Animal Sciences

Stephen P. Schmidt
Professor
Animal Sciences

Stephen L. McFarland
Acting Dean
Graduate School

EVALUATION OF COTTON GIN TRASH AS A ROUGHAGE SOURCE FOR
STOCKER CATTLE

Julie Blair Kennedy

A Thesis

Submitted to

the Graduate Faculty of

Auburn University

in Partial Fulfillment of the

Requirements for the

Degree of

Master of Science

Auburn, Alabama
August 7, 2006

EVALUATION OF COTTON GIN TRASH AS A ROUGHAGE SOURCE FOR
STOCKER CATTLE

Julie Blair Kennedy

Permission is granted to Auburn University to make copies of this thesis at its discretion, upon request of individuals or institutions, and at their expense. The author reserves all publication rights.

Signature of Author

Date of Graduation

VITA

Julie Blair Kennedy, daughter of Anthony Wayne “Tony” Kennedy and Peggy (Rees) Kennedy, was born September 5, 1981 in Albany, Georgia and was raised in Webster County, Georgia. In 2000, she graduated as salutatorian and STAR student of Tri-County High School in Buena Vista, Georgia. She received her Bachelor of Science degree in Animal Science from Berry College in Rome, Georgia in 2004. While there, she was employed at the Rollins Ruminant Research Center on campus. After graduation from Berry College, she received a Graduate Research Assistantship and a Graduate Research Fellowship to attend Auburn University in Auburn, Alabama, where she is currently pursuing her Master of Science degree in Ruminant Nutrition under the guidance of Dr. Darrell L. Rankins, Jr. She will graduate Summa Cum Laude in August of 2006.

EVALUATION OF COTTON GIN TRASH AS A ROUGHAGE SOURCE FOR
STOCKER CATTLE

Julie Blair Kennedy

Master of Science, August 7, 2006
(B.S., Berry College, 2004)

77 Typed Pages

Directed by Darrell L. Rankins, Jr.

Cotton gin trash is a by-product of the cotton ginning industry that may be used as a roughage source in beef cattle. A production trial and a digestibility study were conducted in an effort to determine the feeding value of cotton gin trash in growing cattle. In the production trial, 40 Angus x Continental steers (initial BW = 233 kg) were randomly assigned one of four diets in a 112-day study. There were 2 pens/diet and 5 steers/pen. Each diet was fed ad libitum and was composed of: 1) 45% peanut hulls + 55% cracked corn, 2) 45% peanut hulls + 47% cracked corn + 8% cottonseed meal, 3) 45% gin trash + 55% cracked corn, and 4) 45% gin trash + 47% cracked corn + 8% cottonseed meal. Free choice bermudagrass hay was also provided. Steers were weighed prior to the study and every 28 days throughout the 112-day trial. Steers fed gin trash had faster ADG than those fed diets containing peanut hulls (1.19 kg/d vs. 0.94 kg/d; $P < 0.01$). Diets containing cottonseed meal produced faster ADG than diets without

cottonseed meal (1.14 kg/d vs. 0.99 kg/d; $P < 0.02$). Steers fed gin trash consumed more diet dry matter per day than those fed peanut hulls (10 kg/d and 10.7 kg/d vs. 6.6 kg/d and 8.7 kg/d; $P < 0.05$). Also, cottonseed meal did not improve intake of diets containing gin trash ($P > 0.05$), but did improve intake of diets containing peanut hulls (6.6 kg/d vs. 8.7 kg/d; $P < 0.05$). Hay intake and total dry matter intake were not different among diets ($P > 0.05$). In the digestibility study, 16 Angus x Charolais steers (initial BW = 301 kg) were randomly allotted to one of the four previous diets with 4 steers/diet. The diets were fed for 14 days then the steers were placed in metabolism stalls for a 10-day period with 2 days of acclimation. Fecal output, daily feed intake, and feed refusals were collected during the 8-day study period. Daily dry matter intake was not different among diets ($P > 0.15$). Fiber digestibility (NDF and ADF) did not differ between diets ($P > 0.65$). Diet 3 had a higher DM digestibility and OM digestibility than the other 3 diets ($P < 0.07$ and $P < 0.05$, respectively). Diet 2 had a higher crude protein digestibility than Diet 1 (70.2 vs. 60.3%; $P < 0.05$), but crude protein digestibility of Diet 2 was not different than that of Diets 3 and 4 (65.7 and 62.9%; $P < 0.05$). Cotton gin trash is more digestible than peanut hulls and results in a faster ADG. The addition of cottonseed meal to gin trash diets does not affect cattle performance; however, addition of the protein supplement to diets containing peanut hulls did increase performance.

ACKNOWLEDGEMENTS

The author would like to thank Dr. Darrell L. Rankins, Jr. for his guidance throughout this process. She would also like to thank Dr. Stephen P. Schmidt and Dr. Russell B. Muntifer for serving on her committee, and for their assistance with her graduate program. A thank you also goes to the faculty and staff of the Animal Science Department for their support, assistance, and guidance during her time at Auburn University.

The author would like to thank Brian Gamble and Bill Gregory, the managers of the Wiregrass Experiment Station and the E. V. Smith Research Unit, as well as all of the workers who assisted with her research and collection of data. A special thank you goes to Dr. Ching-Ming (John) Lin for his expertise and assistance with laboratory analysis.

The author would especially like to thank her parents, Tony and Peggy Kennedy, for their love, support, motivation, and for always reminding her that “you can do anything you set your mind to”. She would also like to thank all of her family members and friends that offered love and encouragement through the difficult times. A very special thank you goes to Joshua Lawrence for his unwavering patience and support throughout the entire writing process. He was essential in the completion of this, seemingly, insurmountable task.

Style manual or journal used	<u>Journal of Animal Science</u>
Computer software used	<u>Microsoft Word 2003</u>

TABLE OF CONTENTS

I. LIST OF TABLES	xi
II. INTRODUCTION.....	1
III. REVIEW OF LITERATURE.....	3
Stocker Cattle.....	3
By-product Feeds.....	3
Peanut Hulls.....	7
History of Cotton	8
Harvesting Cotton.....	9
Cotton Ginning.....	10
Cotton By-products.....	11
Gin Trash	15
Gin Trash Disposal Methods	17
Physical Processing Methods.....	26
Chemical Processing Methods.....	29
Summary.....	31
IV. ABSTRACT	33
V. INTRODUCTION.....	35
VI. MATERIALS AND METHODS	37

Feedstuffs	37
Production Trial	37
Digestibility Study	38
Lab Analysis	38
Statistical Analysis.....	39
VII. RESULTS.....	40
Production Trial	40
Digestibility Study	45
VIII. DISCUSSION.....	50
Nutrient Composition.....	50
Production Trial	52
Digestibility Study	55
IX. LITERATURE CITED.....	58

LIST OF TABLES

Table 1. Chemical composition of gin trash and peanut hulls used to formulate experimental diets	41
Table 2. Chemical composition of diets used in the production trial	42
Table 3. Effects of roughage source and protein supplementation on average daily gain of steers in the production trial	43
Table 4. Effects of roughage source and protein supplementation on dry matter intake of steers in the production trial	44
Table 5. Chemical composition of diets used in the digestibility study	46
Table 6. Effects of roughage source and protein supplementation on dry matter intake of steers in the digestibility study	47
Table 7. Effects of roughage source and protein supplementation on apparent digestibility of fiber components	48
Table 8. Effects of roughage source and protein supplementation on apparent digestibility of nutritive components	49

INTRODUCTION

Stocker cattle are a profitable business in Alabama as long as feed costs are low (Prevatt et al., 2005). The goal of the stocker producer is to grow young cattle at a rate of 1.5 lb/d to 2.5 lb/d, while maintaining feed costs at \$.25/lb to \$.30/lb (Rankins, 2002). To accomplish this goal, many producers utilize by-product feeds such as peanut hulls and cotton gin trash.

Peanut hulls have been fed to beef cattle as a low-quality roughage source for many years (Utley and McCormick, 1972; Utley et al., 1973). However, economical use of peanut hulls is limited to the southeastern United States where peanuts are produced. Cotton gin trash is a by-product of the cotton ginning industry. It is composed of stems, leaves, burrs, immature seeds, and sand from the cotton plant. According to Lalor et al. (1975), gin trash is similar to low-quality hay and can be used as a low-quality roughage source in ruminant animals. Cotton is grown in much of the southern United States; therefore, gin trash is available to a larger number of beef producers than peanut hulls.

The nutrient composition of gin trash varies depending on the variety of cotton, the region grown, and the type of harvest method used (Bader et al., 1998). The most variable component is the ash content, which is influenced by the amount of sand that is present (Lalor et al., 1975). Cotton that is grown in sandy areas or that is stripper-harvested will produce gin trash with a high ash content (Lalor et al., 1975; Baker et al.,

1994). Crude protein is the second most variable component and is affected by weather conditions and the amount of immature seed present in the gin trash (Lalor et al., 1975). Despite applications of chemicals on cotton plants, large amounts of chemical residues do not appear to be present in gin trash (Stewart et al., 1998).

Numerous feed studies have been conducted to determine the usefulness of gin trash as a roughage source. Erwin and Roubicek (1958) found that gin trash was palatable and could be fed up to 40% of the diet without adverse affects on gains. Sagebiel and Cisse (1984) reported loss of weight in pregnant cows when gin trash was fed alone, however, the addition of cottonseed improved gains. They also found that the addition of molasses did not increase intake nor improve ADG. Likewise, Hill et al. (2000a) reported loss of weight with 100% gin trash diets and concluded that gin trash could not be used to maintain beef cows without adequate supplementation. Also, Hill et al. (2000b) reported that gin trash could not be used to produce economical gains in growing steers. In view of this data, more studies are needed in an effort to determine the best method to utilize gin trash as a feedstuff.

The purpose of this study was to determine if cotton gin trash could be used to replace peanut hulls in the diets of stocker cattle and to evaluate the effects of using cottonseed meal as a protein supplement in gin trash diets.

REVIEW OF LITERATURE

Stocker Cattle

In Alabama, stockering cattle can be a profitable business if production costs are kept low (Prevatt et al., 2005). There are four types of stocker programs in Alabama: 1) winter grazing stocker calves, 2) winter grazing with supplemental feed, 3) grazing stockpiled fescue, and 4) feeding a by-product and grain diet in a drylot (Prevatt et al., 2005). Each of these stocker programs may require a period of supplemental feeding when grazing is limited. According to Rogers and Poore (1994), the cost of feed is the greatest expenditure for a beef producer. On an energy basis, roughage supplementation is one of the most expensive ingredients (Galyean and Duff, 2002). The goal of the stocker producer is to have 1.5 lb to 2.5 lb of gain/day during the stocker period at a cost of \$.25/lb to \$.30/lb (Rankins, 2002). To achieve this goal, many stocker producers utilize by-product feeds when supplementation is necessary (Rankins, 2002).

By-product Feeds

The food and fiber industry produces many waste products that must be disposed of. Rising costs of solid waste disposal and environmental regulations for incineration have forced manufacturers to develop economical and environmentally friendly ways to dispose of this waste (Chase, 1982; Thomasson, 1990). At the same time, as oil and fertilizer prices rise, the cost of livestock feed will continue to increase. Thus, producers

have developed a need for low-cost, alternative feeds for their livestock. These situations have increased the use of by-product feeds.

By-product feeds are waste products from the food and fiber industry that have nutritive value and can be utilized as alternative sources of energy, protein, or roughage by livestock (Rogers and Poore, 1994; Myer and Hall, 2003). The “waste” nature of the product and the high cost of disposal, drive the manufacturers to sell the by-products to producers at a low-cost (Schingoethe, 1991). Likewise, the availability of these low-cost feeds drives the producer to utilize the by-products, thus, serving as a method of disposal for manufacturing wastes.

There are many types of by-product feeds available from many different industries. The poultry industry produces broiler litter and feather meal. Peanut hulls, peanut skins, hay, and peanut meal are all by-products of the peanut industry, which is prevalent in the South (Hill, 2002). The cotton industry produces cottonseed, cottonseed meal, cottonseed hulls, and gin trash (Rogers et al., 2002). Other by-products include brewer’s grains, cull candy, sunflower meal, and soyhulls (Rankins, 2002). Most by-products are fed to ruminant animals because the rumen is capable of effectively processing the waste products into substrates that can be utilized by the ruminant (Chase, 1982).

The many types of by-products available offer producers a wide array of feed choices. Due to the many differences among types of by-products there are some factors producers must consider before incorporating them into their feeding program (Rankins, 2002). These include transportation and storage, moisture content, nutrient composition, availability, possible contaminants, and feed regulations (Rankins, 2002).

Transportation and storage. By-product feeds are transported as 24-ton loads, and the price of the feed is usually determined by the distance it is hauled (Rankins, 2004). Thus, a producer living close to the point of origin will pay less than one living 100 miles away. Also, many by-products have a low bulk density, which will increase the number of trips required to deliver the same tonnage. The large amount of feed and the low bulk density of many by-products make it necessary for feeds to be stored in an open commodity shed because they will not flow well through traditional feed handling systems (Rogers and Poore, 1994).

Moisture content. Many by-products have a high moisture content, which can lead to several problems. One of these is transportation difficulties. High moisture products are expensive to transport because the producer is paying to ship the excess water as well as the nutritive portion. Thus, it will require more shipments to get the desired nutritive quantity (Rankins, 2002). This will limit the marketability of the product to areas immediately surrounding the manufacturer, because the cost will increase as transport distance increases (Schingoethe, 1991). Storage is a problem also with a high moisture by-product because it needs to be stored in an area that will reduce spoilage, and special facilities may be required (Rankins, 2004). Another consideration is that high moisture feeds containing less than 50% dry matter may reduce dry matter intake (Schingoethe, 1991). Also, some high moisture feeds may not blend well with other feeds in the diet (Rankins, 2004). The producer must also be aware of moisture content when comparing prices of a by-product to another feed. Feeds on a 90% DM basis may appear to cost more per ton, but a producer needs to take into account that with a wet feed they are paying for water as well as dry matter.

Nutrient composition. The nutrient composition of many by-product feeds is highly variable (Schingoethe, 1991). This can be problematic when formulating a diet; therefore, it is important that the producer obtain a nutrient analysis on all by-product feeds. These analyses should contain data for moisture, crude protein, energy, fiber, and minerals as well as other information pertinent to the type of by-product being used (Schingoethe, 1991). The unique nature of by-product feeds makes them susceptible to extreme amounts of specific nutrients, which producers must be aware of and account for in the feeding program (Rankins, 2002). Examples of this are the high mineral content of poultry litter, which will reduce consumption of a mineral mix (Rankins, 2002). Also, whole cottonseed has a high fat content, therefore, intake should be limited to only 20% of the diet (Rogers et al., 2002).

Availability. When formulating a feed program with by-products, it is important to take into account the availability of the by-product. By-products that are associated with a specific season may only be available at certain times of the year (Schingoethe, 1991). Other by-products may be purchased at a lower price during a specific season and stored for future use when the price may be higher (Rankins, 2004). It is also important that the product be available locally. This will reduce transportation costs, thus reducing purchase price of the by-product feed (Rogers and Poore, 1994).

Contaminants and regulations. The “waste” nature of by-products makes them more susceptible to contaminants. Many by-products are the result of unwanted materials that are not fit for human use or consumption. These unwanted materials may be more likely to contain mycotoxins, such as aflatoxin, weed seeds, chemical residues from manufacturing processes or pesticides, and trash that may be harmful to animals

(Rankins, 2002). Producers should be aware of possible contaminants and inspect the by-product before it is fed.

Animals that consume by-product feeds utilize the nutrients in the feed to produce meat and milk used for human consumption. Thus, it is important that these consumer products are not contaminated by alternative feeds in the animal's diet. The American Association of Feed Control Officials (AAFCO) has established definitions for acceptable by-products (Rogers and Poore, 1994). These by-products are sold with a guaranteed analysis, however, the guaranteed analysis will often be much lower than the actual nutrient content (Rankins, 2002). Nontraditional feeds not approved by the AAFCO may be fed, however, it is important to be aware of toxic residues and possible liabilities associated with this practice (Rogers and Poore, 1994).

Peanut Hulls

Peanut hulls are a by-product of the peanut shelling process. After peanuts are picked and dried, shellers separate the nut from the hulls. About 852,340 tons of peanut hulls were produced in the United States in 2004 (NASS, 2005c). Historically, hulls were disposed of by burning but this method is no longer used. As an alternative feed, peanut hulls can be used as a roughage source for all classes of beef cattle (Hill, 2002). The nutritive value of peanut hulls is low, with crude protein, crude fiber, ADF, ash and TDN values of 8%, 63%, 65%, 5%, and 22%, respectively (Waller, 2006). Peanut hulls also have a lower in vitro dry matter disappearance of 24.2% when compared with other roughage sources, such as coastal bermudagrass (59%) and tall fescue (54.6%) (Barton et al., 1974).

Peanut hulls should be fed unground or coarsely ground, usually through a 1.9 cm screen (Hill, 2002). Finely ground hulls and pelleted hulls should not be fed because they increase liver abscesses and will have negative effects on rumen papillae (Hill, 2002). Utley et al. (1974) conducted a study on the effects of feeding ground, unground, and pelleted peanut hulls. They found that unground hulls produced faster average daily gain than the processed hulls and produced feed:gain ratios that were similar to the processed hulls. Also, 56% and 59% of steers fed finely ground and pelleted peanut hulls, respectively, had liver abscesses while only 3% of steers consuming unground peanut hulls had abscesses (Utley et al., 1974).

Utley and McCormick (1972) found that including 10% to 20% peanut hulls in a high concentrate diet promoted weight gain in steers. The amount of feed intake increased in proportion with the amount of hulls in the diet so that steers at all hull levels received similar amounts of concentrate. Utley et al. (1973) found that including 10% to 20% peanut hulls in a feedlot diet will provide adequate fiber to prevent digestive problems without affecting feedlot performance.

History of Cotton

According to Brubaker et al. (1999), cotton is the world's most important textile crop; it is also used to produce cottonseed, oil and protein meal. Cotton has been used to produce fibers since ancient times. The people of India used cotton for fabrics as early as 2000 B.C. (May and Lege, 1999). Alexander the Great introduced cotton to Europe, and its use became more widespread as trade routes opened up (May and Lege, 1999). Cotton textile mills were established in Britain in the early 1600's (May and Lege, 1999). During the Industrial Revolution, advances were made in cotton processing that fueled

the expansion of the world cotton market (May and Lege, 1999). In North America, cotton had been used by Native Americans before European arrival; however, the beginning of the modern cotton industry in North America is traced to Virginia colonists in 1607 (May and Lege, 1999). America was unable to build textile mills due to British laws that prevented the trade of textile technology. Samuel Slater defied these laws in 1789 and brought his knowledge of textile machinery to the United States (May and Lege, 1999). Eli Whitney's development of a cotton gin that could remove the seeds from green seed cotton increased the amount of raw cotton that could be processed in a day (Aiken, 1973). Since that time, the American cotton industry has continued to grow. By the mid-19th century, the United States was producing 2 million bales of cotton; by 1900 this number had increased to over 10 million bales (May and Lege, 1999).

The cotton industry has more than doubled in the last century with the United States producing 22.6 million bales of cotton in 2004 (NASS, 2005a). Cotton production in the United States is concentrated in the south and southwestern United States, including California (NASS, 2005a). Two main types of cotton are produced in the United States. Upland cotton is a short staple cotton similar to the type brought to the United States by the earliest settlers. Many varieties of Upland cotton are grown throughout the United States (Smith et al., 1999). American-Pima is an extra long staple cotton that was derived from Egyptian varieties and introduced in the United States around 1900. It is grown primarily in the southwestern United States (Smith et al., 1999).

Harvesting Cotton

There are two types of cotton harvesters utilized in the United States. They are the spindle picker and the cotton stripper. The spindle picker is the most common and is

utilized by 73% of farmers in the United States (Parnell et al., 1994). It is very selective and only removes well-opened bolls from the plant (Williford et al., 1994). It is used in most areas of the Southeast and will harvest 95% of the cotton in the field (Williford et al., 1994). Cotton picked using a spindle picker may contain 100 lb to 150 lb of trash material for every 1,500 lb of cotton, which is the amount of picker cotton required to produce a 480-lb bale of cotton lint (Parnell et al., 1994). This results in 6% to 10% of the harvested cotton being trash, with 26% of the trash being fines, including sand (Baker et al., 1994).

The cotton stripper runs on a 99% efficiency, but it is not selective (Williford et al., 1994). The cotton stripper will remove all opened and unopened bolls, burrs, sticks, and plant material. The cotton stripper is utilized by only 26% of farmers, primarily in the Southwest (Parnell et al., 1994). This is because dry conditions may cause plants to be small and have a low production, and the cotton stripper will harvest the cotton more efficiently (Williford et al., 1994). The cotton stripper produces 700 lb to 1,000 lb of trash for every 2,200 lb of stripper cotton required to produce a 480-lb bale of cotton lint (Parnell et al., 1994). This results in 30% to 40% trash material with 64% of the trash composed of burrs and 15% fine trash, which includes sand (Baker et al., 1994).

Cotton Ginning

Harvested cotton is processed at the cotton gin, where it undergoes a series of cleaners prior to entering the gin press. Trash differences between picker- and stripper-harvested cotton require it to be processed at different gins. The stripper cotton gin will have more cleaners capable of handling the excessive amounts of trash found in stripper-harvested cotton (Mayfield et al., 1999). The first cleaner the cotton passes through is the

green boll trap, which removes green bolls, rocks, and heavy trash from the cotton (Mayfield et al., 1999). Next, the cotton passes through a cylinder cleaner that removes fine trash particles, including leaves and sand (Mayfield et al., 1999). The stick machine removes burrs and sticks from the cotton (Baker et al., 1994). Hulls and motes are removed by the extractor/feeder prior to entering the gin stand (Baker et al., 1994). The gin stand is where cotton is separated into seed and cotton lint (Mayfield et al., 1999). The seed is collected and used for oil, meal, and feed. The lint enters the lint cleaners, which removes remaining seeds and foreign matter (Baker et al., 1994). Then the lint enters the bale press where the lint is packaged into a uniform bale (Anthony et al., 1994). The trash removed by each cleaner is carried by a central airflow system that combines the trash from each stage of cleaning and collects it in waste piles or trash houses outside the gin (Parnell et al., 1994).

Cotton By-products

Many by-products are produced from the processing of cotton. These include whole cottonseed, cottonseed meal, cottonseed hulls, cotton mote, textile mill waste, and cotton gin trash.

Whole cottonseed. Whole cottonseed is extracted from the cotton plant at the gin and is used for cottonseed oil or as a ruminant feed (Kunkle et al., 2004). Whole cottonseed is a good source for both protein and energy, with crude protein concentrations around 24% and TDN at 90% (NRC, 2000). Whole cottonseed does not require processing prior to feeding, which reduces cost (Poore and Rogers, 1995). Two problems associated with feeding cottonseed are its high fat content and the presence of gossypol. Whole cottonseed has a fat content of 17.5%, so feed levels should not exceed

20% of diet dry matter in mature cows and 15% diet dry matter in growing cattle (Rogers and Poore, 1994; NRC, 2000; Rogers et al., 2002).

Gossypol is a yellow pigment found in cotton glands that is toxic to livestock. Nonruminant animals are especially susceptible to the effects of gossypol because they do not have a method of detoxifying it. Ruminant animals are only mildly susceptible because they can detoxify gossypol by binding free gossypol to soluble proteins within the rumen (Reiser and Fu, 1962). This system may be overwhelmed if the amount of gossypol consumed exceeds the amount of available protein (Morgan, 1989). Tolerance levels of gossypol in cattle are 0.18% gossypol for mature cattle and 0.04% gossypol for young calves (Morgan, 1989). The largest concentration of gossypol is found in the seeds and roots (Rogers et al., 2002). Gossypol content in cottonseed may be affected by the species and variety of the cotton plant as well as environmental conditions, such as rainfall and temperature (Pons et al., 1953). In general, cottonseed contains between 0.002% to 6.64% gossypol (Morgan, 1989). Gossypol is classified as a polyphenolic binaphthyl dialdehyde, and is found in two forms, free and bound (Rogers et al., 2002). The bound form is non-toxic because it is bound to proteins and is not released during digestion, but the free form can be toxic to the animal if consumed. Gossypol has two stereoisomers (+) and (-) (Kim et al., 1993). The (-) isomer is more toxic than the (+) isomer (Kim et al., 1993). Pima cotton, which is grown in Arizona, New Mexico, and parts of west Texas, contains 52% to 57% of the (-) gossypol isomer (Kim et al., 1993). Upland cotton, which is the most common cotton grown in the southern United States, has only 32% to 49% of the (-) gossypol isomer (Kim et al., 1993).

Gossypol can affect feed intake, cause weight loss, affect reproduction, and prolonged exposure can cause cardiac effects that may lead to death (Merck, 1998). These symptoms are rarely seen in ruminant animals because they are capable of detoxifying the gossypol. The largest concern of gossypol in ruminant animals is that the (-) isomer can cause male infertility (Kim et al., 1993). Gossypol affects the germinal epithelium and mitochondria in the tail of sperm, causing a reduction in sperm count as well as sperm that are not structurally correct (Randel et al., 1992). In ruminant animals, infertility is reversible. Once gossypol is removed from the diet, normal sperm are produced within sixty days, and the negative reproductive effects are removed (Rogers and Poore, 1995). The cottonseed fed to ruminants in the Southeast are from Upland cotton, which does not have a large concentration of the (-) isomer that causes male infertility. For this reason, feeding cottonseed in the Southeast is not as large an issue as it would be in the Southwest. However, it is still recommended that bulls be limited to 5 lbs of cottonseed/day, while cows may consume anywhere from 5 lbs to 8 lbs/day (Rogers and Poore, 1995). Cottonseed should not be fed to preruminant calves, but growing cattle can be fed up to 15% cottonseed in the diet without adverse effects (Rogers et al., 2002).

Cottonseed meal. Cottonseed meal is used as a protein supplement in cattle. It is produced as a by-product of cottonseed oil extraction. Cottonseed meal has a crude protein content around 46% and a TDN value around 75% (NRC, 2000). Cottonseed meal contains gossypol at levels between 0.8% to 1.4%, which makes it more toxic than whole cottonseed (Rogers et al., 2002). This is because the processing of cottonseed into meal releases the free gossypol from the pigment glands (Rogers et al., 2002).

Cottonseed meal is produced by four mechanisms: 1) screw processing, 2) prepressed-solvent extraction, 3) expander-solvent extraction, and 4) direct-solvent extraction (Rogers et al., 2002). Each method produces cottonseed meal with gossypol concentrations lower than 0.13%, except for the direct-solvent extraction, which results in a concentration of 0.3% (Rogers et al., 2002). The direct-solvent extraction frees bound gossypol making the meal more toxic to the animal (Poore and Rogers, 1995). The presence of gossypol makes cottonseed meal toxic to nonruminant animals, therefore, it can be obtained cheaper than soybean meal (Poore and Rogers, 1995).

Cottonseed hulls. Cottonseed hulls are another by-product of cottonseed oil production (Poore and Rogers, 1995). Cottonseed hulls have a low nutritional value, with 45% TDN and crude protein between 4% and 5% (NRC, 2000; Waller, 2006). When compared with other roughages, cottonseed hulls increase feed intake and reduce feed efficiency (Swingle, 1995). They also slow outflow of particles from the rumen, altering digestion of other diet ingredients (Goetsch et al., 1986). Cottonseed hulls do not contain significant concentrations of gossypol and will not cause toxicity (Rogers et al., 2002). Cottonseed hulls can be used as a hay replacer in high grain diets, especially when grinding hay is not desired (Rankins, 2004). Three kilograms of cottonseed hulls can be used to replace 2 kg of an average quality hay in the diet (Rogers et al., 2002).

Cotton mote. Gin motes are fibers and immature cotton seeds removed during the ginning process (Rogers et al., 2002). They contain very little leaf, stem, and soil (Poore and Rogers, 1995). Cotton motes can be marketed to gins that re-gin them and produce a useable fiber called linters, which are used in high-quality papers and explosives (Rogers et al., 2002). Motes that are not re-ginned can be used as a cattle feed. Cotton motes

have good nutritional value as a roughage, with 45% to 50% TDN and 7% to 9% crude protein (Rankins, 2004).

Textile mill by-product. Textile mill by-product is a waste product of the yarn manufacturing process (Rogers et al., 2002). Cotton yarn manufacture produces five types of waste: 1) stem, leaf, and cottonseed from the lint, 2) short cotton fibers, 3) dust, 4) waste yarn and slivers (long strands ready for spinning), and 5) foreign materials discarded on the floor (Poore and Rogers, 1995). This waste is combined into 2 groups: sweeps and textile mill by-products. Sweeps consist of waste yarn, slivers, and foreign matter that is unfit to be fed to animals (Rogers et al., 2002). Textile mill by-products contain stem, leaf, cottonseed, short fibers, and dust, which can be fed to ruminants (Rogers et al., 2002). This waste can be obtained in 700 lb bales or in briquettes that are 2- to 3-inch pellets (Poore and Rogers, 1995). Textile mill by-product has a crude protein value around 8% and a TDN value between 50% and 60% (Rogers et al., 2002). Feed studies with textile mill waste have shown that when included as 20% (DM basis) of the diet, it is similar to sorghum silage, and it has a digestibility similar to low-quality fescue hay and high quality bermudagrass hay (Luginbuhl et al., 1994; Poore, 1994). Textile mill by-product should not be fed 28 days prior to slaughter (Poore and Rogers, 1995). Mature cows should receive no more than 10 lb/d and stocker cattle should receive no more than 20% of their diet in textile mill by-product (Rogers et al., 2002).

Gin Trash

Cotton gin trash is composed of stems, leaves, burrs, immature seeds, and sand removed from cotton at the gin. There are about 2.8 million tons of gin trash produced in the United States each year (Thomasson et al., 1998). It is estimated that about 40,000

tons are produced in Alabama alone (NASS, 2005b). The size and type of the gin determines the amount of gin trash that it will produce. A picker-harvested gin, processing 15,000 bales of seed cotton per year may produce 1,000 tons of gin trash in one season (Thomasson et al., 1991). A 15,000 bale/year stripper-harvested gin may produce upwards of 5,000 tons of gin trash per season (Castleberry and Elam, 1999). Cotton gin trash is composed of 22% permanganate lignin, which causes it to decompose at a very slow rate (Conner and Richardson, 1987). This poses a problem at the gin because the gin trash accumulates rapidly and must be disposed of, because it occupies space, poses a fire hazard, and may lead to water contamination (Thomasson et al., 1998).

In the past, ginners utilized incineration and dumping to dispose of gin trash (Thomasson, 1990). However, public awareness of pollution issues and strict environmental laws have increased the cost and decreased public opinion of these disposal methods. Incinerating gin trash began to decline after the 1970 Federal Clean Air Act, because the burning method required to meet emissions standards was too costly for gins (Thomasson, 1990). In the 1965 to 1966 ginning season, 37% of gin trash across the Cotton Belt was incinerated (Reeves, 1976). By 1991, 23% of the gin trash produced in the Midsouth was disposed of by incineration (Thomasson et al., 1991). Today, incinerating gin trash has been phased out and is no longer practiced (Thomasson et al., 1998). Dumping gin trash in a solid waste disposal landfill is allowed, however, dumping costs have increased and this practice has no profit potential (Thomasson, 1990).

Gin Trash Disposal Methods

Castleberry and Elam (1998) conducted a survey of 82 Texas gins and found that gins pay an average of \$1.44/ton to dispose of cotton gin trash. The cost of disposal ranged from a net profit of \$8/ton to a cost of \$10/ton. They estimated that Texas ginners pay an average of \$1.8 million on gin trash disposal each year. This disposal cost, coupled with the large amount of gin trash produced and environmental issues, has driven ginners to utilize alternative methods of disposal in an effort to decrease pollution and make a profit. These methods include: 1) soil amendment, 2) compost, and 3) livestock feed.

Soil Amendment. Soil amendment is an alternative method of disposal in which the raw gin trash is spread on fields. Research shows that applying 3 tons to 6 tons of gin trash per acre will significantly increase crop yields. In a study done by Box and Walker (1959), applying 6 tons per acre of cotton land increased lint yields by 27 lb. Harper (1950) showed that applying 3 tons per acre improved seed cotton yields by 20%. Fryrear and Koshi (1974) showed lint yield increases of 16% to 36% when 5 tons per acre were applied. They also found that the largest yield increases occurred during the drier years. Not all studies exhibit yield increases. Millhollon et al. (1984) reported that after seven years of gin trash application, there was no improvement in seed cotton or lint yields.

Spreading gin trash improves yield by retaining moisture in the soil. A 4.1 tons per acre application rate can increase water retention 31% to 50% (Fryrear, 1979). Gin trash also increases organic matter as well as reducing the bulk density of the soil (Koshi and Fryrear, 1973). A reduction in soil temperatures to a depth of 30 inches has also

been observed with gin trash amendments (Fryrear and Koshi, 1974). Gin trash improves soil fertility by fertilizing the soil and allowing it to retain nutrients (Thomasson, 1990). A study by Fryrear (1979) on 5-year test plots, two years after amendments were stopped, showed that spreading gin trash increased phosphorus concentrations from 12.5 lb/acre to 29.4 lb/acre. Potassium was also increased from 620 lb/acre to 1067 lb/acre. However, gin trash amendments do not lead to a significant increase in nitrogen, copper, magnesium, or calcium oxide.

Cotton gin trash has the potential to improve yield, however, there are some disadvantages to using it as a soil amendment. Cotton gin trash may spread weeds and diseases to the growing cotton plants (Mayfield, 1991). Many farmers stopped using it as a soil amendment because of these problems (Mayfield, 1991). However, a study by Box and Walker (1959) showed no differences in weed and disease infestations over a six year period. Fryrear (1979) did note a higher weed infestation but it was easily controlled by cultivation.

Composting. Composting the gin trash is a solution to the problems of raw soil amendment. Composting destroys *verticillium dahliae*, which is a fungus that causes *verticillium* wilt, a disease in cotton plants (Parnell et al., 1980; Hills et al., 1981). Hills et al. (1981) also reported that composting destroyed weed seeds, such as bermudagrass, watergrass, and pigweed. Composting gin trash does not require a microorganism inoculant or the addition of nitrogen (Griffis and Mote, 1978). However, it does require high internal temperatures, moisture, and aeration. Composting begins when the internal temperature reaches 113°F and ends when the temperature will not stay above 113°F (Reddell et al., 1975). Composting gin trash requires adequate aeration by turning and

60% moisture, achieved by wetting the pile (Hills, 1982). Material can be composted within 3 to 7 weeks if proper moisture and aeration are applied (Alberson and Hurst, 1964; Hills, 1982). If the pile is kept wet but is not aerated, it will take about 3 months for the gin trash to decompose (Alberson and Hurst, 1964). Composting gin trash will reduce dry matter weight by 50% and volume by 60% (Parnell et al., 1980). The composted gin trash will contain about 3% nitrogen, however, only about 7% to 30% of the nitrogen will be immediately available to the plant (Parnell et al., 1980; Seiber et al., 1982).

Livestock Feed. Gin trash can be used as a roughage in ruminant diets.

According to Lalor et al. (1975), gin trash contains moderate protein and energy, and is comparable to low-quality bermudagrass hay. Palatability is good as long as gin trash does not exceed 40% of the diet (Lalor et al., 1975). Gossypol is not considered to be a problem in gin trash because it contains only a small number of immature seeds.

Gin trash is inexpensive and often can be purchased for the price of transporting it from the gin (Kunkle et al., 2004). On average, the purchase price for gin trash is about \$30/ton (Myer and Hall, 2003). When compared to corn at \$2.50/bu to \$3.00/bu, gin trash has a value of \$49/ton to \$58/ton (McCann and Stewart, 2000). Gin trash has an energy value of \$54.25/ton when compared to a 52% TDN hay that is \$60/ton (Rankins, 2004).

The nutrient composition is highly variable, depending on harvest method, cotton variety, weather, area grown, and the amount of dirt in the gin trash (Bader et al., 1998). The ash content, which consists of sand and minerals, is the most variable component and can range from 8% to 28% depending on the amount of sand that is present (Lalor et al.,

1975). A high ash content is found in gin trash that has not been cleaned, was stripper-harvested, or that has been produced from cotton grown in areas with sandy soil (Lalor et al., 1975; Axe et al., 1982; Baker et al., 1994). Crude protein is the second most variable component, and it is related to the amount of immature seed in the gin trash as well as weather conditions during the growing season (Lalor et al., 1975).

As with any by-product feed, there are some problems associated with feeding gin trash. Transportation is an issue because gin trash has a low bulk density, which may make it necessary to haul multiple loads to achieve the requested tonnage (Kunkle et al., 2004). This will increase the price of the gin trash because the largest expense in using by-products is transportation (Rankins, 2002). Transportation problems can be alleviated by grinding, pelleting, baling, or moduling the gin trash (Lalor et al., 1975; Rogers et al., 2002). Once received, the gin trash should be stored in a commodity bin or in covered piles.

Moisture may also be a problem with gin trash because many gins spray their trash piles with water to reduce dust and speed up decomposition (Rankins, 2002). This excess moisture may promote mold growth and encourage production of mycotoxins (Wakelyn et al., 1972; Lalor et al., 1975). The moisture may also cause the pile to heat to the extent that the nutrients are bound and become less digestible (Rankins, 2004).

A disadvantage to feeding gin trash is the lack of established tolerance levels of chemical residues in gin trash (Buser, 2001). Cotton is treated with many types of pesticides and defoliant throughout the growing season. Many of the chemicals used are labeled as “Do not feed to livestock any crop material that has had this chemical applied”

(Buser, 2001). Arsenic was the most common residue found in gin trash, however, it was taken off the market as a defoliant in 1993 (Rogers et al., 2002).

Seiber et al. (1979) conducted a study that measured the amount of chemical residue found in various stages of gin trash production. The chemicals studied were the defoliants, S, S, S-tributyl phosphorotrithioate (DEF) and paraquat, and the insecticide, toxaphene. The cotton was planted in test plots and treated according to the labels. Samples were taken after application, prior to harvest, after harvest, prior to ginning, and five months after harvest. DEF residues decreased from 169 ppm to 33 ppm, twelve days after application. Gin trash from this crop had DEF residue concentrations of 50.6 ppm immediately following harvest with a less than 20% decline to 41.2 ppm after five months of storage. The largest concentration of DEF occurred in the non-lint portion, which had a residue concentration of 46.4 ppm, five months after storage. The residue concentration of the lint portion five months after storage was 7.7 ppm. DEF tolerance concentrations are 4 ppm in cottonseed and 6 ppm in cottonseed hulls. The tolerance concentration for paraquat in cottonseed is 0.5 ppm. The waste from the cotton treated with paraquat was separated into lint and non-lint portions, with the non-lint portion having the highest concentration of residue at 9.3 ppm. There was no significant decline in the amount of paraquat present in either portion of the gin trash during storage. Toxaphene levels were reduced from 661 ppm to 135 ppm, fifty days after application. Gin waste tested after ginning showed toxaphene residues at 61.4 ppm. After five months of storage this had been reduced to 43 ppm, which is more than the 5 ppm tolerance level of toxaphene in cottonseed. After the storage period the lint portion had toxaphene levels of 10.2 ppm while the non-lint portion had levels of 51.5 ppm. Seiber et

al. (1979) concluded that residues from these three chemicals will be present in the waste, with the highest concentrations occurring in the non-lint portions.

Researchers in Georgia analyzed trash from 21 gins and found no significant concentrations of chemicals, except for DEF (Stewart et al., 1998). The amount of DEF ranged from 0 ppm to 25.6 ppm, with an average of 4.49 ppm. The average amount in the gin trash was less than the cottonseed tolerance concentration of 6 ppm, however, until tolerance concentrations are established for gin trash, it cannot be guaranteed as safe to feed.

Gin trash may also be contaminated with weed seeds, depending on the amount of weeds in the field prior to harvest (Kunkle et al., 2004). These weeds can be spread throughout pastures during feeding. Other contaminants include mycotoxins and unwanted trash.

The permanganate lignin content of gin trash can be as high as 22%, which is comparable with the lignin content of wood (Conner and Richardson, 1987). This high percentage of lignin not only slows decomposition in soil but also decreases digestibility by microorganisms in the rumen (Conner and Richardson, 1987). Energy from gin trash is derived from the breakdown of cellulose in the rumen (Conner and Richardson, 1987). As a plant matures, lignin content increases, which decreases cellulose digestibility (Allinson and Osbourn, 1970). Plant residues in gin trash are at full maturity and, therefore, have low energy digestibility. Another disadvantage of gin trash is the limited availability of protein (Brown et al., 1979). This may be due to lignification, silification, or insufficient dry matter intake (Sagebiel and Cisse, 1984).

Another factor that affects gin trash digestibility is the amount of sand picked up by the harvester. Large amounts of sand lower digestibility because minerals depress cellulose digestibility (Van Soest, 1994). The mechanism is unknown but could be due to the silica in the sand inhibiting rumen activity by creating trace metal deficiencies in the microorganisms (Smith and Nelson, 1975). Thus, the amount of sand that is present in the gin trash will decrease its digestibility. The amount of sand present is dependent on the harvest method and if the cotton was produced in a sandy area or where the wind blows frequently (Lalor et al., 1975).

Numerous feed studies have been conducted to determine the usefulness of gin trash as a livestock feed. One of the earliest studies was conducted by Erwin and Roubicek (1958). In an effort to determine the feeding value and palatability of unprocessed gin trash, they fed 30 steers one of 5 diets over an 83-day growing period. The diets consisted of: 1) hehari silage, 2) hehari silage + milo grain + gin trash, 3) milo grain + gin trash, 4) gin trash, and 5) gin trash + molasses. Also, the diets were fed in a 76-day fattening period with the addition of milo grain to Diets 4 and 5. They found that Diets 1, 2, and 3 had faster ADG than Diets 4 and 5. Feed efficiency was similar among Diets 1, 2, and 3, but Diet 1 produced more efficient gains than Diets 4 and 5. During the fattening period, ADG of Diets 2, 4, and 5 were similar, while steers on Diet 1 and Diet 3 had slower gains. They concluded that gin trash was palatable, because dry matter intake of diets containing gin trash was higher than that of diets containing silage. Also, the addition of molasses did not improve intake or feed efficiency of the gin trash. A second study by Erwin and Roubicek (1958) was conducted to evaluate the effects of feeding different levels of gin trash. In this study, 108 steers were fed one of six diets for 91

days. The diets consisted of hehari silage:cotton gin trash in ratios of: 1) 100:0, 2) 80:20, 3) 60:40, 4) 40:60, 5) 20:80, and 6) 0:100. They found that there was no significant difference between Diets 1, 2, and 3, but once gin trash was increased beyond 60% of the diet in Diets 4, 5, and 6, ADG slowed significantly.

Brown et al. (1979) conducted a study on feeding gin trash to dairy cattle. Four diets were fed to 12 Holstein cows in a double reversal experiment. The four diets consisted of: 1) 50% concentrate + 50% alfalfa, 2) 50% concentrate + 40% alfalfa + 10% gin trash, 3) 50% concentrate + 20% alfalfa + 30% gin trash, and 4) 50% concentrate + 50% gin trash. They found that weight gains were not affected by the presence of gin trash in the diets. The diets containing 30% and 50% gin trash decreased milk yield and increased milk fat percentage. Protein digestibility was significantly reduced as the amount of gin trash in the diet increased. However, the additional gin trash in the diets caused fat digestibility to increase. Brown et al. (1979) concluded that gin trash may be fed but only when the price is low enough to counteract the decrease in production.

A study by Sagebiel and Cisse (1984) evaluated the effects of feeding cotton gin trash to pregnant beef cows. In the first trial, 90 pregnant cows were fed one of three diets for 90 days. The diets were as follows: 1) 100% gin trash, 2) 30% gin trash + 70% sorghum silage, and 3) 100% sorghum silage. The cows on Diet 3 gained weight while those on Diet 2 maintained their weight and cows on Diet 1 lost weight. Cows fed all gin trash did not consume enough feed to meet their TDN requirements, but they did exceed their protein requirement by 38%. The significant weight loss led Sagebiel and Cisse (1984) to conclude that some of the protein was unavailable due to lignification or silification. In the second trial, 75 pregnant cows were fed one of three diets: 1) 90% gin

trash + 10% molasses, 2) 80% gin trash + 20% molasses, and 3) 70% gin trash + 30% molasses for 56 days. They concluded that the amount of molasses did not significantly improve ADG nor did it increase gin trash intake. This is similar to the data reported by Erwin and Roubicek (1958). The third trial consisted of feeding 80 pregnant cows one of four diets consisting of gin trash fed ad libitum and varying levels of whole cottonseed: 1) 1.135 kg/d, 2) 2.27 kg every other day, 3) 2.27 kg/d, and 4) 4.54 kg every other day. Inclement weather and a reduced supply of cotton gin trash skewed the data and caused the trial to conclude prematurely. Initial observations showed that cottonseed increased intake of cotton gin trash and cows fed daily consumed more gin trash than those fed every other day. In all trials they observed that younger cows tended to lose more weight than the older cows, however, this trend was not significant.

Hill et al. (2000a) conducted a study on feeding gin trash to non-pregnant beef cows. Twenty-four cows were fed one of two diets for 55 days. The diets consisted of: 1) free choice gin trash and 2) free choice gin trash and 1.36 kg/d corn. Cows on Diet 2 had an ADG of 0.018 kg/d, while cows on Diet 1 lost 0.136 kg/d. Both groups had lower ultrasound backfats at Day 55. From this data, Hill et al. (2000a) concluded that the nutritive value of gin trash cannot maintain beef cows without adequate supplementation.

A study by Hill et al. (2000b) was conducted to determine the value of feeding gin trash to steers. Thirty-six steers were allotted one of four diets over an 18-day period. The diets consisted of: 1) 5.67 kg gin trash + 1.75 kg corn, 2) 4.91 kg gin trash + 2.47 kg corn, 3) 4.06 kg gin trash + 3.29 kg corn, and 4) 3.17 kg gin trash + 4.15 kg corn. In Diets 2, 3, and 4 they found that the increased level of corn needed for the desired gain decreased fiber digestibility (NDF and ADF). From this, Hill et al. (2000b) concluded

that gin trash cannot be used effectively by growing beef cattle to produce economical gains.

Physical Processing Methods

The poor digestibility of cotton gin trash as well as its low bulk density has led to the development of methods that improve its feeding value and ease of handling.

Physical treatments such as cleaning, grinding, and extruding will improve both quality and handling of cotton gin trash.

Cleaning. The nutritive value of gin trash is reduced by large amounts of sand (Axe et al., 1982). Cotton grown in sandy areas and stripper-harvested cotton will contain larger amounts of sand (Lalor et al., 1975; Baker et al., 1994). Smith and Nelson (1975) stated that silica reduced forage digestion by binding to minerals and reducing the availability of minerals needed by cellulolytic microbes. This mineral deficit inhibits proper fermentation and reduces the digestibility of gin trash. Cleaning gin trash is the simplest method of improving the feeding value. Cleaning removes dirt and fine trash particles from the gin trash. Cleaning is performed by screening the gin trash and allowing fine particles to be removed (Axe et al., 1982).

In a study by Axe et al. (1982) gin trash was cleaned using a 20-mesh screen that removed fine trash particles. The leftover lint, stem, leaf, and burr fragments were then used in a diet fed to steers. The feeding trial showed that screening gin trash lowered ash content (25%), improved rate of gain (9.6%), increased feed intake (6.4%), and improved feed conversion (3.2%) as compared to the uncleaned gin trash.

Grinding. According to Castleberry and Elam (1998), grinding increases gin trash digestibility as well as increases bulk density, which makes handling easier. Improved

digestibility is supported by Han et al. (1983), who indicated that direct physical contact between hydrolytic agents and cellulose molecules is necessary for cellulose hydrolysis. They also stated that increasing accessible cellulose surface area will increase the rate of hydrolysis (Han et al., 1983). This increase in surface area can be achieved by grinding. Pordesimo et al. (2005) tested the in vitro dry matter digestibility (IVDMD) of gin trash with particle sizes of 2-mm and 0.5-mm. Grinding to 0.5 mm resulted in an IVDMD of 47.8%, while the 2-mm grind produced an IVDMD of only 33.8%.

Extruding. Extrusion is a process that combines mixing, pressure, and shear to create frictional forces that generate heat and create a uniform product (Buser, 2001). In the extrusion process, the raw materials are screened to remove fine particles, such as dirt. The raw materials are then ground and mixed together. Next, they undergo conditioning, cooking, and flaking. Then, the mixture is extruded into chips or pellets (Thomasson et al., 1998). Extruding gin trash will produce a uniform product with a higher feed value and reduced concentrations of chemical residues (Thomasson et al., 1998). Gin trash extrusion requires the use of a lubricating material, such as whole cottonseed, to improve flow through the extruder (Buser, 2001). Mixing with cottonseed dilutes chemical residues present in the gin trash and improves the nutritive value (Thomasson et al., 1998; Buser, 2001). Buser (2001) reports a minimum of 25% cottonseed is necessary to maintain flow and create a uniform product. Less than 25% cottonseed produced a product that was loose and fluffy. Thomasson et al. (1998) disagrees, stating that even at 25% cottonseed, the product was a loose and fluffy mixture, and that at least 50% cottonseed is needed to produce a good product.

Extruding gin trash and cottonseed will also cause a reduction in chemical residues (Thomasson et al., 1998; Buser, 2001). In a study by Thomasson et al. (1998), chemicals were applied to the gin trash prior to extruding to ensure measurable amounts. After extruding, there were significant reductions in the insecticide, methomyl (66%), the defoliant, Dropp (90%), and gossypol content of the cottonseed. Buser (2001) conducted a study in which the insecticides, methyl parathion and lambda cyhalothrin, and the defoliants, tribufos and thidiazuron were applied to gin trash prior to extrusion with cottonseed. In this study, extrusion significantly reduced levels of methyl parathion (27%) and tribufos (40%). The concentration of lambda cyhalothrin was reduced, but not significantly, however, this may have been affected by an outlier. Buser (2001) also conducted a multiple pass study in which the gin trash/cottonseed mixture was extruded four times to determine the effects on chemical residues. In the study, methyl parathion and thidiazuron levels were reduced significantly by multiple extrusions (52% and 95%, respectively). Lambda cyhalothrin levels were reduced 28%, but not significantly. Tribufos levels were increased by extrusion, but this is thought to be an anomaly in the residue analysis.

Thomasson et al. (1998) reported that extrusion did not have a negative effect on feed value, and the addition of cottonseed actually improved nutritive value. Buser (2001) noted a 30% decrease in soluble protein after the first extrusion and a decrease in crude protein (10%) and TDN (4%) in the multiple extrusion process.

COBY method. The cotton by-product process (COBY), another type of extrusion method, was developed by researchers at the USDA, ARS Cotton Production and Processing Research Unit in Lubbock, Texas in 2002 (Middleton et al., 2001). This

extrusion method utilizes a starch slurry composed of 240 g of feed grade starch and 1 L of water. This is applied at a rate of 6% starch per weight of gin trash. The mixture is then extruded at an average temperature of 110°C (Holt et al., 2003). Holt et al. (2003) found that gin trash processed by the COBY method can be fed up to 30% of the diet without adverse effects. They also found that the COBY process improved feed:gain ratio and weight gain when compared with ground gin trash. They reported that including a feed-grade enzyme improved weight gain, and replacing a natural protein supplement with a slow-release urea supplement reduced intake and performance.

Chemical Processing Methods

The low digestibility of gin trash is a result of the high amount of lignification of carbohydrates in the mature cotton plant (Conner and Richardson, 1987). Chemical treatment makes these carbohydrates available to microbes by breaking the lignified matrices (Arndt et al., 1980). The treatment most commonly used on gin trash is sodium hydroxide (Conner and Richardson, 1987). Sodium hydroxide treatment works by solubilizing hemicellulose without affecting cellulose content (Klopfenstein, 1978). It also increases the digestion rate of cellulose and hemicellulose by breaking bonds between the cellulose fractions and lignin, without reducing lignin content (Klopfenstein, 1978). Treatment with sodium hydroxide involves applying a 25% sodium hydroxide solution at a rate of 7.3 kg/100 kg dry matter, which results in a rate of 4% sodium hydroxide on a dry matter basis (Conner and Richardson, 1987). Feeding sodium hydroxide treated residues may cause a sodium overload in the animal (Arndt et al., 1980).

Arndt et al. (1980) studied the effects of gin trash treated with sodium hydroxide on lambs. Gin trash was treated with a 4% sodium hydroxide solution and then mixed with a diet that included sorghum grain and soybean meal. The first trial measured the effects of treated and untreated gin trash that composed 70% of the diet. The diet containing sodium hydroxide-treated gin trash had a dry matter digestibility 35% greater than the untreated diet (54.7% vs 40.4%) and organic matter digestibility was improved similarly (42% vs 57%). The sodium hydroxide-treated diet increased urine volume by almost 100%, because sodium hydroxide acts as a diuretic. In another trial by Arndt et al. (1980), diets contained 70% gin trash, but the amount of treated and untreated gin trash was variable. Diets included: 1) untreated, 2) 1/3 treated:2/3 untreated, 3) 2/3 treated:1/3 untreated, and 4) 100% treated gin trash. The treated gin trash represented 0%, 23%, 47%, and 70% of the total diet, respectively. Feeding Diets 2 and 3 improved dry matter digestibility and organic matter digestibility. When all of the gin trash was treated, a 5% reduction in dry matter digestibility and a 4.9% reduction in organic matter digestibility were observed. From this it is inferred that optimum dry matter digestibility and organic matter digestibility are obtained when only 40% to 50% of the total diet is treated with sodium hydroxide. This could be due to the increased amount of sodium hydroxide causing a decrease in rumen retention time or having negative effects on microorganisms in the rumen (Arndt et al., 1980). The differences between the two studies were caused by variations in the diets and differences in particle size of the ground gin trash. These studies also indicated that the feeding of sodium-hydroxide treated gin trash increased mineral requirements for potassium, chloride, and magnesium.

Pordesimo et al. (2005) studied the in vitro dry matter digestibility of gin trash. In vivo digestibility is lower than in vitro digestibility because of a faster rumen turnover, increased osmotic pressure, and the possibility of toxicity to microorganisms (Arndt and Richardson, 1985). In the study by Pordesimo et al. (2005) the gin trash was ground to 2 mm and treated with 4% sodium hydroxide and 6% sodium hydroxide. The 4% sodium hydroxide-treated gin trash had an improved IVDMD of 60.6%, while the 6% sodium hydroxide improved IVDMD by 70.5%. Even though the 6% sodium hydroxide solution is more effective at improving digestibility, it is not feasible because the high sodium concentration can cause sodium overload in the animal (Arndt et al., 1980).

Studies have also been conducted involving treatment of cotton waste products with oxidizing agents such as ozone. Ozone is a highly reactive, penetrating molecule that attacks the carbon-carbon double bonds of lignin's phenolic constituents (Ben-Ghedalia et al., 1980). A study by Ben-Ghedalia et al. (1980) indicated that treating cotton straw with ozone decreased lignin content 50%, cellulose IVDMD by 30%, and improved IVDMD by more than 100% from 29.6% to 60.5%. This was due to a conversion of cell walls into cell contents. While ozone is a very effective method of improving gin trash digestibility, it is not used because utilizing it on a large scale is not economically feasible (Conner and Richardson, 1987).

Summary

By-product feeds provide producers with low-cost alternative feeds for cattle while reducing waste in the environment. Gin trash is a by-product feed that can be used as a forage supplement in beef cattle. It is palatable and its nutrient composition is similar to that of low-quality hay. Gin trash may contain chemical residues from

pesticides and defoliants applied to cotton prior to harvesting. Tolerance levels have not been established for chemical residues in gin trash, however, there have been no adverse affects observed from the feeding of gin trash. The low digestibility of gin trash can be improved by cleaning, grinding, extruding, and by application of sodium hydroxide. Studies involving gin trash have shown that when fed at less than 30% of the diet with supplementation, weight can be maintained. The purpose of this study was to compare the digestibility and feeding value of cotton gin trash in growing beef cattle with that of peanut hulls.

ABSTRACT

Two trials were conducted to evaluate the feeding value of cotton gin trash as it compares with peanut hulls, with or without supplemental protein, as a roughage source in beef cattle. In Trial 1, 40 Angus x Continental steers (initial BW = 233 kg) were allotted randomly to one of the following 4 diets: 1) 45% peanut hulls + 55% cracked corn, 2) 45% peanut hulls + 47% cracked corn + 8% cottonseed meal, 3) 45% gin trash + 55% cracked corn, and 4) 45% gin trash + 47% cracked corn + 8% cottonseed meal. There were 2 pens/diet with 5 steers/pen. Steers were allowed ad libitum access to diets and bermudagrass hay was offered free choice in each pen. Steers were weighed initially and every 28 days throughout the 112-day trial. Data were analyzed as a 2 x 2 factorial, with factors being two roughage sources with or without cottonseed meal. Steers fed gin trash gained faster than those fed peanut hulls (1.19 vs 0.94 kg/d; $P < 0.01$) and had greater dry matter feed intake (10.3 vs 7.6 kg/d; $P < 0.05$). Diets containing cottonseed meal produced faster ADG than those containing no cottonseed meal (1.14 vs 0.99 kg/d; $P < 0.02$), and had greater dry matter feed intake (9.7 vs 8.3 kg/d; $P < 0.05$). A roughage source by protein supplementation interaction was detected for feed intake. Diet 2 had a higher feed intake than Diet 1 (8.7 vs 6.6 kg/d; $P < 0.05$). Dry matter feed intake of diets containing gin trash was not affected by the presence of cottonseed meal ($P > 0.05$). Hay intake and total dry matter intake were not different among diets ($P > 0.05$). In Trial 2,

16 Angus x Charolais steers (initial BW = 301 kg) were assigned randomly to one of the 4 diets used in Trial 1 (4 steers/diet). Steers were fed their assigned diet for 14 days and then placed in individual metabolism stalls for an 8-day digestibility study. Dry matter intake did not differ among diets and averaged 6.0 kg/d or 2.0% of BW. Fiber digestibility (NDF or ADF) was not different among diets. A significant cottonseed meal by roughage source interaction was detected for DM, OM and CP digestibilities. Dry matter and OM digestibilities were greater for Diet 3 compared with the other three diets ($P < 0.07$). Digestibilities of the 4 diets were as follows: 73, 73, 80 and 69% for DM, respectively, and 72, 73, 80 and 72% for OM, respectively. Crude protein digestibility was least ($P < 0.05$) for Diet 1 (60%) and greatest for Diet 2 (70%), with Diets 3 and 4 being intermediate (66% and 63%). Cotton gin trash was more digestible and resulted in faster ADG than peanut hulls when fed to growing cattle. The addition of cottonseed meal to gin trash diets did not affect cattle performance; however, addition of the protein supplement to diets containing peanut hulls did increase performance.

INTRODUCTION

Peanut hulls have been used as a low-quality roughage source in beef cattle diets for many years (Utley and McCormick, 1972; Utley et al., 1973). They are combined with a protein or energy source to provide a low-cost feed for stocker cattle. While producing cost-efficient gains, peanut production is limited to a small area of the southeastern United States; therefore, the option of feeding peanut hulls cost effectively is not widely available to cattle producers. Cotton gin trash, a by-product of the ginning process, is composed of stems, leaves, burrs, immature seeds, and sand from the cotton plant. Like peanut hulls, gin trash can be used as a low-quality roughage source (Lalor et al., 1975). An advantage to using gin trash over peanut hulls is that the cotton growing industry encompasses a larger region of the United States, making the gin trash available to more cattle producers.

The nutritive quality of gin trash varies depending on the variety of cotton, region grown, and the type of harvest method used (Bader et al., 1998). The ash content is the most variable component of gin trash and may be very high in areas with sandy soils or in stripper-harvested areas (Lalor et al., 1975; Baker et al., 1994). Protein concentration is also variable depending upon growing conditions of the cotton plant and the amount of immature seed remaining in the gin trash (Lalor et al., 1975). Chemical residues from

cotton plant applications do not appear to be present at concentrations that pose a problem to the animal or the product (Stewart et al., 1998).

Studies have shown that gin trash is palatable to ruminants and can produce gains when supplemented with a protein or energy source (Erwin and Roubicek, 1958; Sagebiel and Cisse, 1984; Hill et al., 2000a). Many studies have been conducted on feeding gin trash to beef cattle; however, more data is needed on the effects of feeding gin trash to growing cattle. A production trial in which ADG and dry matter intake was measured, and a digestibility study were conducted to determine whether diets containing gin trash produce more efficient gains than diets composed of peanut hulls when fed to growing steers. The addition of cottonseed meal to two of the diets compared the effects of protein supplementation on average daily gain, feed intake, and digestibility.

MATERIALS AND METHODS

A production trial was conducted at the Wiregrass Research and Extension Center in Headland, Alabama and a digestibility study was conducted at the E. V. Smith Beef Research Unit in Tallassee, Alabama. All experimental procedures were reviewed and approved by the Auburn University Institutional Animal Care and Use Committee.

Feedstuffs

The gin trash was obtained from a gin in Headland, Alabama, that processes spindle-picked cotton. Peanut hulls were obtained from the State Peanut Lab in Headland, Alabama. The corn was grown in Henry County, Alabama.

Production Trial

Forty Angus x Continental steers (initial BW = 233 kg) were allotted randomly to one of four diets for a 112-day study. There were two pens/diet and five steers/pen. The diets consisted of 1) 45% peanut hulls + 55% cracked corn, 2) 45% peanut hulls + 47% cracked corn + 8% cottonseed meal, 3) 45% gin trash + 55% cracked corn, and 4) 45% gin trash + 47% cracked corn + 8% cottonseed meal. Steers had ad libitum access to diets and bermudagrass hay was offered free choice. The steers were weighed prior to the study and every 28 days throughout the 112-day trial. Also, feed intake was measured on a weekly basis throughout the study.

Digestibility Study

Sixteen Angus x Charolais (BW = 301 kg) steers were assigned randomly to one of the four previous diets, with 4 steers/diet, and housed in metabolism stalls for an 8-day digestibility study. Steers were fed their respective diets for 14 days prior to entering the metabolism stalls. The steers were placed in the metabolism stalls for 10 days with a 2-day acclimation period prior to the start of the trial. The stalls provided access to water and feed bunks. Movement was restricted to moving backwards or forwards, and lying down. Rubber mats were used to collect fecal output, while urine was washed through a slatted floor. Each day, fecal output, daily feed intake, and feed refusals were weighed and a 10% sample was taken. Each sample was dried at 55°C until dry and stored for further analysis.

Lab Analysis

All samples from diets, feed refusals, and fecal output were ground to pass a 1 mm screen using a Wiley mill. Dry matter and ash analyses were performed on each sample according to the Association of Official Analytical Chemists (AOAC, 1995). The amount of crude protein in each sample was determined using the Kjeldahl method (AOAC, 1995). Concentrations of NDF and ADF for all samples were determined sequentially using the method outlined by Van Soest et al. (1991). This procedure was carried out using an ANKOM^{200/220} Fiber Analyzer and ANKOM Technology F57 Filter Bags.

Statistical Analysis

Data was analyzed as a completely randomized design with a 2 x 2 factorial arrangement of treatments using GLM procedures of SAS. Pen was the experimental unit in the production trial, and animal was the experimental unit for the digestibility study.

RESULTS

Chemical composition of the gin trash and peanut hulls used to formulate the diets for the production trial and digestibility study are presented in Table 1.

Production Trial

The diets fed to steers in the production trial are shown in Table 2. One steer was removed from Diet 2 due to failure to respond to treatment for pneumonia. Data for this diet was adjusted accordingly. For ADG, there was no roughage source x protein supplementation interaction ($P > 0.25$; Table 3). Steers fed gin trash had faster ADG than those fed peanut hulls ($P < 0.01$; Table 3). Also, diets containing cottonseed meal produced greater ADG than diets without cottonseed meal ($P < 0.02$; Table 3). A roughage source x protein supplement interaction was detected for feed intake ($P < 0.05$; Table 4). Feed intake was greater for diets containing gin trash than diets composed of peanut hulls ($P < 0.05$; Table 4). Feed intake of diets containing gin trash was not improved by the addition of cottonseed meal ($P > 0.05$; Table 4), whereas cottonseed meal significantly improved intake of the diet containing peanut hulls ($P < 0.05$; Table 4). Daily hay intake and total dry matter intake was not different among diets ($P > 0.05$; Table 4).

Table 1. Chemical composition of gin trash and peanut hulls used to formulate experimental diets

Nutrient ^a	Gin trash	Peanut hulls
DM, %	93.1	92.0
OM, %	73.4	96.5
NDF, %	69.2	88.7
ADF, %	60.8	79.1
CP, %	12.4	5.4

^a Dry matter basis

Table 2. Chemical composition of diets used in the production trial

Nutrient ^a	Diet ^b			
	1	2	3	4
DM, %	91.4	91.3	90.9	91.1
OM, %	93.2	95.3	89.6	89.7
NDF, %	42.9	44.4	42.1	49.0
ADF, %	33.3	34.8	31.7	38.4
CP, %	9.6	12.3	11.5	13.6

^a Dry matter basis

^b Diet 1 = 45% peanut hulls + 55% cracked corn, Diet 2 = 45% peanut hulls + 47% cracked corn + 8% cottonseed meal, Diet 3 = 45% gin trash + 55% cracked corn, Diet 4 = 45% gin trash + 47% cracked corn + 8% cottonseed meal

Table 3. Effects of roughage source and protein supplementation on average daily gain of steers in the production trial^a

Variable	Roughage source		Protein supplement		SE ^b
	Gin trash	Peanut hulls	No CSM	CSM	
ADG, kg/d	1.19 ^c	0.94 ^d	0.99 ^e	1.14 ^f	0.043

^a Analysis of variance showed no roughage source x protein supplement interaction ($P > 0.25$). Therefore, main effect means are shown.

^b Standard error of the mean ($n = 4$)

^{cd} Main effect means with different superscripts differ ($P < 0.01$)

^{ef} Main effect means with different superscripts differ ($P < 0.02$)

Table 4. Effects of roughage source and protein supplementation on dry matter intake of steers in the production trial^a

Variable	Gin trash		Peanut hulls		SE ^b
	No CSM	CSM	No CSM	CSM	
Feed intake, kg/d	10.0 ^c	10.7 ^c	6.6 ^d	8.7 ^e	0.26
Hay intake, kg/d	2.3	1.8	2.8	2.0	0.65
Total intake, kg/d	12.3	12.5	9.4	10.7	0.67

^a Analysis of variance showed a roughage source x protein supplement interaction ($P < 0.05$) for feed intake

^b Standard error of the mean ($n = 2$)

^{cde} Means with different superscripts differ ($P < 0.05$)

Digestibility Study

Table 5 shows the composition of diets fed to steers in the digestibility study. For the digestibility study, there was no roughage source x protein supplement interaction for daily dry matter intake or dry matter intake as a percent of body weight ($P > 0.15$; Table 6). There were no significant differences among the diets for these variables. Analysis of fiber (NDF and ADF) digestibility data showed no roughage source x protein supplement interaction ($P > 0.65$; Table 7). In addition, neither roughage source, nor protein supplement, affected fiber digestibility. Dry matter digestibility and organic matter digestibility were greater in diets of gin trash without cottonseed meal than in the other 3 diets ($P < 0.07$ and $P < 0.05$, respectively; Table 8). The crude protein digestibility of peanut hulls with cottonseed meal was greater than the crude protein digestibility of peanut hulls without cottonseed meal ($P < 0.05$; Table 8), but neither was significantly different from the crude protein digestibility of diets containing gin trash ($P > 0.05$; Table 8).

Table 5. Chemical composition of diets used in the digestibility study

Nutrient ^a	Diet ^b			
	1	2	3	4
DM, %	96.2	96.3	95.9	96.4
OM, %	96.9	96.5	82.8	83.1
NDF, %	45.2	51.6	42.5	48.2
ADF, %	34.9	40.9	34.7	39.1
CP, %	8.1	10.1	11.9	14.7

^a Dry matter basis

^b Diet 1 = 45% peanut hulls + 55% cracked corn, Diet 2 = 45% peanut hulls + 47% cracked corn + 8% cottonseed meal, Diet 3 = 45% gin trash + 55% cracked corn, Diet 4 = 45% gin trash + 47% cracked corn + 8% cottonseed meal

Table 6. Effects of roughage source and protein supplementation on dry matter intake of steers in the digestibility study^a

Variable	Roughage source		Protein supplement		SE ^b
	Gin trash	Peanut hulls	No CSM	CSM	
Body wt, kg	299	303	301	301	8.53
Daily DM intake, kg/d	5.89	6.17	5.54	6.51	0.404
DM intake, % BW	1.97	2.03	1.83	2.17	0.116

^a Analysis of variance showed no roughage source x protein supplement interaction ($P > 0.15$). Therefore, main effect means are shown.

^b Standard error of the mean (n = 4)

Table 7. Effects of roughage source and protein supplementation on apparent digestibility of fiber components^a

Variable	Roughage source		Protein supplement		SE ^b
	Gin trash	Peanut hulls	No CSM	CSM	
NDF, %	55.7	50.0	49.9	55.9	4.58
ADF, %	52.0	46.0	44.5	53.5	5.73

^a Analysis of variance showed no roughage source x protein supplement interaction ($P > 0.65$). Therefore, main effect means were shown.

^b Standard error of the mean ($n = 4$)

Table 8. Effects of roughage source and protein supplementation on apparent digestibility of nutritive components^a

Variable	Gin trash		Peanut hulls		SE ^b
	No CSM	CSM	No CSM	CSM	
DM, %	80.0 ^c	69.2 ^d	72.8 ^d	72.6 ^d	1.82
OM, %	80.3 ^e	71.5 ^f	72.3 ^f	72.7 ^f	1.61
CP, %	65.7 ^{ef}	62.9 ^{ef}	60.3 ^e	70.2 ^f	2.16

^a Analysis of variance showed a roughage source x protein supplement interaction (P < 0.07)

^b Standard error of the mean (n = 2)

^{cd} Means with different superscripts differ (P < 0.07)

^{efg} Means with different superscripts differ (P < 0.05)

DISCUSSION

Nutrient Composition

The nutrient composition of the gin trash used to formulate the diets for this study is shown in Table 1. The values are similar to published tabular values, which are DM: 91%, CP: 10%, NDF: 70%, ADF: 51%, and Ash: 14% (Preston, 2006). The largest discrepancy was that the gin trash used in these experiments contained greater concentrations of ash. According to Lalor et al. (1975), the ash concentration is the most variable component of gin trash and can range from 8% to 28%. Ash concentration is influenced by the amount of sand in the gin trash; therefore, cotton grown in sandy areas or that has been stripper-harvested will produce gin trash that has a higher ash concentration (Lalor et al., 1975; Baker et al., 1994). The gin trash used in these studies was produced from spindle-picked cotton raised in the Wiregrass region of south Alabama, which has sandy soils. The high ash concentration (i.e., 26.6%) of the gin trash used in these experiments may be attributed to the sandy soils in the region.

Crude protein is the second most variable component of gin trash (Lalor et al., 1975). The crude protein concentration of the gin trash used in the diets was 12.4%. This value is higher than the crude protein reported by Brown et al. (1979) of 5.6% and that of Whiting and Schuh (1988) at 8.7%. However, it is lower than values of Hill et al. (2000a) and Hill et al. (2000b) of 13.6% and 15.1%, respectively. Crude protein

concentrations are attributed to the amount of immature seed remaining in the gin trash and the weather conditions that existed during growth and harvest of the cotton plant (Lalor et al., 1975). The moderately high crude protein of the gin trash used in this study leads us to infer that either the weather conditions were favorable during the growing season or that a substantial amount of immature seed was present in the gin trash.

The gin trash had an ADF content of 60.8%, which is higher than the value reported by Waller (2006) of 46%. However, it is similar to values reported by Brown et al. (1979) and Hill et al. (2000b) of 55.1% and 63.5%, respectively.

The composition of the peanut hulls used in the study is given in Table 1. Preston (2006) gives the composition of peanut hulls as DM: 91%, CP: 7%, NDF: 74%, ADF: 65%, and Ash: 5%. Utley and McCormick (1972) reported values of DM: 90%, CP: 8.4%, ADF: 68.3%, and Ash: 3.6%. The peanut hulls used in these studies had a crude protein concentration of only 5.4%. However, the crude protein concentration of the diets formulated with the peanut hulls suggests that the peanut hull crude protein concentration should be around 8%. Random samples of the peanut hulls were taken from the pile used to formulate the diets. Then, these samples were pooled to form a composite sample that was analyzed four times for crude protein concentration using the Kjeldahl method as outlined by the AOAC (1995). Crude protein values of 2.31%, 5.44%, 5.41%, and 5.28% were obtained with this method. Thus, the discrepancy is attributed to an unrepresentative sample as opposed to an error with analysis. The NDF and ADF values are slightly higher than values that were previously reported; however, they are consistent with the NDF and ADF composition of the diets used in the study.

The high fiber values correspond with the low crude protein composition of the peanut hulls and may also be attributed to an unrepresentative sample.

Production Trial

In the production trial, there was a significant increase in feed intake by steers consuming gin trash diets compared with those consuming peanut hull diets ($P < 0.05$; Table 4). The intake of peanut hulls may be lower because they are bulky and have a low digestibility; therefore, they take up more space in the rumen and have a slower rate of passage. This is supported by Blaxter et al. (1961) and Conrad et al. (1964) who found that dry matter intake increases as digestibility and, therefore, rate of passage, increases. Also, Campling and Balch (1961) reported that the amount of dry matter in the rumen affects voluntary intake. This fill effect causes the animal to consume less dry matter, leading to a decreased feed intake. Therefore, the more digestible a feedstuff, the faster it disappears from the rumen, and the more feed can be consumed.

Steers consuming diets consisting of peanut hulls with cottonseed meal had a greater feed intake than those consuming diets of only peanut hulls ($P < 0.05$; Table 4). Previous studies have shown an increase in digestibility of low-quality forages when a protein supplement is provided (Kartchner, 1980; Guthrie and Wagner, 1988; DeCurto et al. 1990b). This increased digestibility leads to a faster rate of passage, which leads to an increase in dry matter intake (Blaxter et al., 1961; Campling and Balch, 1961; Kartchner, 1980; Guthrie and Wagner, 1988). However, in this study, the digestibility of peanut hull diets with and without cottonseed meal was similar; therefore the increase in feed intake cannot be attributed to an increase in digestibility. The diets containing peanut hulls with

cottonseed meal may result in a faster rate of passage than peanut hull diets without cottonseed meal, which may have led to a greater feed intake.

All steers in this trial consumed in excess of 3% of their body weight per day. Typically, growing steers will not consume more than 3% of their body weight each day (NRC, 2000). The high dry matter intake observed in this trial is consistent with previous studies conducted using by-product feeds in growing steers in which dry matter intake exceeded 3% of body weight (Rankins and Gamble, 2000). Also, some of the dry matter intake may be attributed to feed that was not consumed, but was lost on the ground or otherwise unaccounted for in data collection.

A roughage source x protein supplement interaction did not occur with ADG. Steers fed diets containing gin trash gained 21% faster than those fed diets containing peanut hulls ($P < 0.01$; Table 3). This increase in gain may be attributed to the higher dry matter intake of the diets containing gin trash than those containing peanut hulls (Table 4). The ADG of diets containing gin trash was 1.19 kg/d (Table 3). This data is similar to the unpublished data reported by Rogers et al. (2002) that showed cows fed gin trash and cottonseed gained 1.1 kg/d. It is also similar to ADG reported by Erwin and Roubicek (1958) of 0.9 to 1.05 kg/d for diets composed of milo + gin trash and silage + milo + gin trash. However, Sagebiel and Cisse (1984) reported that diets containing sorghum silage + gin trash and gin trash + molasses resulted in weight loss. Hill et al. (2000a) also reported weight loss on diets consisting of gin trash alone and gains of only 0.018 kg/d for diets containing gin trash + corn.

Steers consuming diets containing peanut hulls had an ADG of 0.94 kg/d (Table 3). This is less than gains of 1.13 kg/d reported by Rankins and Gamble (2000) with a

similar diet consisting of 55% corn and 45% peanut hulls. Utley et al. (1973) reported gains of 1.17 kg/d on a diet consisting of 70% corn + 10% crude protein supplement + 20% peanut hulls. Utley and McCormick (1972) reported ADG of 1.44 kg/d, 1.49 kg/d, and 1.48 kg/d for diets containing 10%, 20%, and 30% peanut hulls in addition to corn and hay.

Diets containing cottonseed meal produced ADG that were 13% faster than ADG from diets without cottonseed meal ($P < 0.02$; Table 3). This is supported by previous research that reported improved gains when a protein supplement was included in the diet (Foster et al., 1945; Speth et al., 1962; Clanton and Zimmerman, 1970; DelCurto et al., 1990a). In this trial, the cottonseed meal increased rate of gain by stimulating dry matter intake for both peanut hull and gin trash diets. In the diet containing peanut hulls with cottonseed meal, the 284-kg steers (anticipated mature weight = 544 kg) gaining 1.05 kg/d, should have consumed 8 kg of dry matter at 10.34% crude protein, giving a total of 830 g of crude protein (NRC, 2000). The steers in the trial actually consumed 10.7 kg dry matter (3.76% of BW) at 12.3% crude protein with a total of 1,320 g of crude protein. At this concentration of crude protein, the steers should have gained over 1.36 kg/d (NRC, 2000). Likewise, the 300-kg steers (anticipated mature weight = 544 kg) gaining 1.23 kg/d, fed diets containing gin trash with cottonseed meal required 8.22 kg of dry matter at 12.1% crude protein with a total of 995 g of crude protein being consumed (NRC, 2000). The steers actually consumed 12.5 kg (4.2% of BW) at 13.6% crude protein; therefore the steers, should have gained over 1.36 kg/d. Diets without cottonseed meal were not deficient in protein and steers on diets with cottonseed meal did not gain as expected; therefore, it was determined that energy was a limiting factor in terms of gains,

and the addition of cottonseed meal only improved ADG by stimulating dry matter intake. This is consistent with studies that have found that a protein supplement increases consumption and leads to faster gains (Kartchner, 1980; Guthrie and Wagner, 1988).

Digestibility Study

In the digestibility study, there were no significant differences among feed intake of the diets ($P > 0.15$; Table 6). Steers in the digestibility study consumed less dry matter per day than steers in the production trial (Table 4 and Table 6). These differences may be attributed to the different feeding methods used in the two trials. In the production trial the diets were offered with ad libitum access, while in the digestibility study diets were limited to the approximate amount each individual animal would consume to reduce the amount of orts produced. Also, many of the steers on Diets 3 and 4 consumed all of the feed allotted to them each day and may have consumed more if it had been offered. Another factor contributing to the reduced intake in the digestibility study may be stress, induced by changing environments and being housed in metabolism stalls.

The addition of cottonseed meal significantly improved the crude protein digestibility of the peanut hulls over peanut hull diets without cottonseed meal ($P < 0.05$; Table 8). As previously stated, using a protein supplement, such as cottonseed meal, increases the digestibility of low-quality forages (Kartchner, 1980; Guthrie and Wagner, 1988; DelCurto et al., 1990b). Cottonseed meal did not significantly improve crude protein digestibility of diets containing gin trash ($P > 0.05$; Table 8). The cottonseed meal may not have improved crude protein digestibility of the gin trash because the gin trash supplied an adequate amount of crude protein to meet the steer's needs without the addition of cottonseed meal. According to the NRC (2000), growing steers weighing

around 300 kg (anticipated mature weight = 544 kg) and gaining 1.23 kg/d would require 995 g of crude protein/day. The steers fed diets containing gin trash with cottonseed meal consumed an average of 1,700 g of crude protein/day, while steers fed diets containing gin trash without cottonseed meal consumed 1,414 g of crude protein/day. This suggests that the amount of crude protein fed was sufficient without the addition of cottonseed meal; therefore, cottonseed meal did not improve crude protein digestibility.

The data shows a significant increase in the dry matter digestibility and the organic matter digestibility of the diet composed of gin trash without cottonseed meal than the other three diets ($P < 0.07$ and $P < 0.05$, respectively; Table 8). This is contrary to what would be expected of gin trash because the high ash content should decrease digestibility.

Fiber digestibility (NDF and ADF) was not significantly different among diets containing gin trash or peanut hulls ($P > 0.65$; Table 7), nor was there a difference among diets with or without cottonseed meal ($P > 0.65$; Table 7). NDF and ADF digestibility of diets containing gin trash were 55.7% and 52%, respectively. These numbers are greater than those reported by Hill et al. (2000b) of 13.7% and 11.8%, respectively, when a similar diet of 43% gin trash and 57% corn was used. Hill et al. (2000b) attributed their low fiber digestibilities to a reduction in fiber digestibility caused by the large amount of corn in the diet. This is supported by Chase and Hibberd (1987) who stated that fiber digestibility decreases when corn is fed at more than 1 kg/d. No significant reductions in fiber digestibility were observed in our study as a result of the presence of corn in the diet.

According to the results obtained in this study, using gin trash in diets for stocker cattle resulted in faster ADG than using peanut hulls. Also, the addition of a protein supplement to the gin trash diet did not significantly increase gains. However, cottonseed meal did increase gains in diets containing peanut hulls and may be more effective in gin trash diets that have a lower crude protein concentration.

LITERATURE CITED

- Aiken, C. S. 1973. The evolution of cotton ginning in the southeastern United States. *Geogr. Rev.* 63: 196-224.
- Alberson, D. M., and W. M. Hurst. 1964. Composting cotton gin waste. USDA/ARS Publication ARS 42-102, 16 pp.
- Allinson, D. W., and D. F. Osbourn. 1970. The cellulose-lignin complex in forages and its relationship to forage nutritive value. *J. Agric. Sci.* 74: 23-36.
- Anthony, W. S., D. W. Van Doorn, and D. Herber. 1994. Packaging lint cotton. In: W. S. Anthony and W. D. Mayfield (eds.) *Cotton Ginners Handbook*. p 119-142.
- AOAC. 1995. Official methods of analysis. Association of Official Analytical Chemists, Washington, D.C.
- Arndt, D. L., and C. R. Richardson. 1985. Effect of sodium hydroxide, monensin, and pH on rumen turnover rate of cotton plant by-product by lambs. *Nutr. Rep. Int.* 31: 687-694.
- Arndt, D. L., C. R. Richardson, R. C. Albin, and L. B. Sherrod. 1980. Digestibility of chemically treated cotton plant by-product and effect on mineral balance, urine volume and pH. *J. Anim. Sci.* 51: 215-223.
- Axe, D., D. Addis, J. Clark, J. Dunbar, W. Garrett, N. Hinman, and R. Zinn. 1982. Feeding value of cleaned and uncleaned gin trash. *Proc. West. Sec. Am. Soc. Anim. Sci.* 33: 57-65.
- Bader, M. J., R. K. Bramwell, R. L. Stewart, and G. M. Hill. 1998. Gin trash studies conducted in Georgia. *Beltwide Cotton Production Research Proceedings* 2: 1698-1699.
- Baker, R. V., W. S. Anthony, and R. M. Sutton. 1994. Seed cotton cleaning and extracting. In: W. S. Anthony and W. D. Mayfield (eds.) *Cotton Ginners Handbook*. p 69-89.

- Barton, F. E., II, H. E. Amos, W. J. Albrecht, and D. Burdick. 1974. Treating peanut hulls to improve digestibility for ruminants. *J. Anim. Sci.* 38: 860-864.
- Ben-Ghedalia, D., G. Shefat, and J. Miron. 1980. Effect of ozone and ammonium hydroxide treatments on the composition and *in-vitro* digestibility of cotton straw. *J. Sci. Food Agric.* 31: 1337-1342.
- Blaxter, K. L., F. W. Wainman, and R. S. Wilson. 1961. The regulation of food intake by sheep. *Anim. Prod.* 3: 51-61.
- Box, J., and H. J. Walker. 1959. Cotton burs for soil improvement. Texas Ag. Exp. Stat., Texas A & M University Publication MP-476, 8 pp.
- Brown, W. H., G. D. Halbach, J. W. Stull, and F. M. Whiting. 1979. Utilization of cotton gin trash by lactating dairy cows. *J. Dairy Sci.* 62: 793-796.
- Brubaker, C. L., F. M. Bourland, and J. F. Wendel. 1999. The origin and domestication of cotton. In: C. W. Smith and J. T. Cothren (eds.) *Cotton: Origin, History, Technology, and Production*. p 3-4. John Wiley & Sons, Inc.
- Buser, M. 2001. Extruding cotton gin trash by-products to reduce chemical residues. *J. of Cotton Sci.* 5: 92-102.
- Campling, R. C., and C. C. Balch. 1961. Factors affecting voluntary intake of food by cows. 1. Preliminary observations on the effect, on the voluntary intake of hay, of changes in the amount of the reticulo-ruminal contents. *Br. J. Nutr.* 15: 523-530.
- Castleberry, M., and E. Elam. 1998. Production and disposal/utilization of cotton gin waste from the Texas High and Low plains. In: *Beltwide Cotton Production Research Proceedings*. p 1669-1674.
- Castleberry, M., and E. Elam. 1999. Economics of cotton gin waste as a roughage ingredient in cattle feedlot rations on the Texas High plains. In: *Beltwide Cotton Production Research Proceedings*. p 1472-1478.
- Chase, C. C., Jr, and C. A. Hibberd. 1987. Utilization of low-quality native grass hay by beef cows fed increasing quantities of corn grain. *J. Anim. Sci.* 65: 557-566.
- Chase, L. E. 1982. Using by-product feedstuffs in ruminant rations. In: *Proc. Cornell Nutrition Conference*. p 107-110.
- Clanton, D. C., and D. R. Zimmerman. 1970. Symposium on pasture methods for maximum production in beef cattle: Protein and energy requirements for female beef cattle. *J. Anim. Sci.* 30: 122-132.

- Conner, M. C., and C. R. Richardson. 1987. Utilization of cotton plant residues by ruminants. *J. Anim. Sci.* 65: 1131-1138.
- Conrad, H. R., A. D. Pratt, and J. W. Hibbs. 1964. Regulation of feed intake in dairy cows. I. Change in importance of physical and physiological factors with increasing digestibility. *J. Dairy Sci.* 47: 54-62.
- DelCurto, T., R. C. Cochran, L. R. Corah, A. A. Beharka, E. S. Vanzant, and D. E. Johnson. 1990a. Supplementation of dormant tallgrass-prairie forage: II. Performance and forage utilization characteristics in grazing beef cattle receiving supplements of different protein concentrations. *J. Anim. Sci.* 68: 532-542.
- DelCurto, T., R. C. Cochran, D. L. Harmon, A. A. Beharka, K. A. Jacques, G. Towne, and E. S. Vanzant. 1990b. Supplementation of dormant tallgrass-prairie forage: I. Influence of varying supplemental protein and (or) energy levels on forage utilization characteristics of beef steers in confinement. *J. Anim. Sci.* 68: 515-531.
- Erwin, E. S., and C. B. Roubicek. 1958. Utilization of cotton gin trash by growing and fattening steers. *J. Anim. Sci.* 17: 133-139.
- Foster, J. E., H. H. Biswell, and E. H. Hostetler. 1945. Comparison of different amounts of protein supplements for wintering beef cows on forest range in the southeastern coastal plain. *J. Anim. Sci.* 4: 387-394.
- Fryrear, D. W. 1979. Management of blank rows in dry-land skip-row cotton. USDA/ARS, 12 pp.
- Fryrear, D. W., and P. T. Koshi. 1974. Surface mulching with cotton gin trash improves sandy soils. USDA/ARS, Conservation Research Report no. 18, 10 pp.
- Galyean, M. L., and G. C. Duff. 2002. Feeding growing-finishing beef cattle. In: R. O. Kellems and D. C. Church (eds.) *Livestock Feeds and Feeding*. p 371. Prentice Hall, Upper Saddle River, New Jersey.
- Goetsch, A. L., F. N. Owens, and B. E. Doran. 1986. Whole or ground corn and different roughage sources in high concentrate diets for beef heifers. *Okla. Agric. Exp. Sta. Res. Rep.* MP-118: 154.
- Griffis, C. L., and C. R. Mote. 1978. Cotton gin trash composting studies. *Arkansas Farm Research*, July-August, p. 3.
- Guthrie, M. J., and D. G. Wagner. 1988. Influence of protein or grain supplementation and increasing levels of soybean meal on intake, utilization, and passage rate of prairie hay in beef steers and heifers. *J. Anim. Sci.* 66: 1529-1537.

- Han, Y. W., E. A. Catalano, and A. Ceigler. 1983. Treatments to improve the digestibility of crop residues. In: E. J. Soltes (ed.) *Wood and Agricultural Residues: Research on use for Feed, Fuels, and Chemicals*. p 217-238. Academic Press, NY.
- Harper, H. J. 1950. Cotton burs and cotton bur ashes as fertilizer for cotton on a claypan soil. *Okla. Agric. Exp. Stat.*, 8 pp.
- Hill, G. M. 2002. Peanut by-products fed to cattle. *Vet. Clin. Food Anim.* 18: 295-315.
- Hill, G. M., R. S. Watson, R. N. Gates, G. L. Newton, R. L. Stewart, and M. J. Bader. 2000a. Feeding cotton gin trash to beef cows in confinement during winter. *J. Anim. Sci.* 78 (Suppl. 2): 25.
- Hill, G. M., R. S. Watson, G. L. Newton, R. L. Stewart, R. N. Gates, and M. J. Bader. 2000b. Cotton gin trash and dry rolled corn dietary intake and digestibility in growing beef steers. *J. Anim. Sci.* 78 (Suppl. 2): 25.
- Hills, D. J. 1982. Composting gin trash in California. In: *Proceedings of the Symposium on Cotton Gin Trash Utilization Alternatives*, National Science Foundation: 63-86.
- Hills, D. J., R. G. Curley, J. D. Knutson, J. N. Seiber, W. L. Winterlin, R. S. Rauschkolb, G. S. Pullman, and C. L. Elmore. 1981. Composting treatment for cotton gin trash fines. *Transactions of the ASAE*: 14-19.
- Holt, G. A., C. R. Richardson, G. A. Nunnery, K. F. Wilson, T. C. Bramble, L. D. Rea, and T. C. Wedegaertner. 2003. Performance of growing heifers fed diets containing cotton gin by-products extruded by the COBY process. *Prof. Anim. Sci.* 19: 404-409.
- Kartchner, R. J. 1980. Effects of protein and energy supplementation of cows grazing native winter range forage on intake and digestibility. *J. Anim. Sci.* 51: 432-438.
- Kim, H. L., M. C. Calhoun, and S. W. Kuhlmann. 1993. Isomers of gossypol in cottonseed and cottonseed meal. *J. Anim. Sci.* 71(Suppl. 1): 30.
- Klopfenstein, T. 1978. Chemical treatment of crop residues. *J. Anim. Sci.* 46: 841-848.
- Koshi, P. T., and D. W. Fryrear. 1973. Effect of tractor traffic, surface mulch, and seedbed configuration on soil properties. In: *Proceedings of the Soil Science Society of America* 37: 758-762.
- Kunkle, W. E., R. L. Stewart, and W. F. Brown. 2004. Using by-product feeds in beef supplementation programs. *University of Florida Ext. Ser. Bulletin AN101*.

- Lalor, W. F., J. K. Jones, and G. A. Slater. 1975. Cotton gin trash as a ruminant feed. Cotton Gin and Oil Mill Press: 28-29.
- Luginbuhl, J. M., K. R. Ponds, and J. C. Burns. 1994. Short fiber cotton textile-mill waste as a feed resource for cattle. *J. Anim. Sci.* 72: 1467.
- May, O. L., and K. E. Lege. 1999. Development of the world cotton industry. In: C. W. Smith and J. T. Cothren (eds.) *Cotton: Origin, History, Technology, and Production*. p 65-97. John Wiley & Sons, Inc.
- Mayfield, W. 1991. Gin trash utilization: What are the options?. In: *Beltwide Cotton Production Research Proceedings*. p 496-497.
- Mayfield, W. D., W. S. Anthony, S. E. Hughs, R. V. Baker, and W. F. Lalor. 1999. Ginning. In: C. W. Smith and J. T. Cothren (eds.) *Cotton: Origin, History, Technology, and Production*. p 683-707. John Wiley & Sons, Inc.
- McCann, M. A., and R. Stewart. 2000. Use of alternate feeds for beef cattle. *UGA Cooperative Ext. Ser.* 406.
- Merck. 1998. Gossypol poisoning. In: S. E. Aiello (ed.) *The Merck Veterinary Manual*. p 2039-2041. Merck & Co., Inc., Whitehouse Station, N.J.
- Middleton, M., E. Elam, G. Holt, and W. Laird. 2001. Preliminary estimates of the cost of extrusion processing of cotton gin by-product as a livestock feed. In: *Beltwide Cotton Production Research Proceedings*. p 266-270.
- Millhollon, E. P., G. Barker, and G. Rasbury. 1984. The effects of gin compost on cotton production. *Annual Research Report, Louisiana Exp. Sta., Red River Res. Stat., Bossier City, LA*, p 33-36.
- Morgan, S. E. 1989. Gossypol as a toxicant in livestock. *Vet. Clin. Food Anim.* 5: 251-262.
- Myer, R. O., and M. B. Hall. 2003. Alternative feeds for beef cattle. *University of Florida Ext. Ser. Bulletin AN128*.
- NASS. 2005a. Cotton ginnings 2004 summary. National Agricultural Statistics Service, Agricultural Statistics Board, USDA: 43-44.
- NASS. 2005b. Cotton ginnings: Running bales by crop, state, and United States, crop years 2003-2004. National Agricultural Statistics Service, Agricultural Statistics Board, USDA.

- NASS. 2005c. Statistical highlights: Field crops: Acreage, yield, production, price, value, and stocks. National Agricultural Statistics Service, Agricultural Statistics Board, USDA.
- NRC. 2000. Nutrient requirements of beef cattle. 7th revised ed. National Academy of Science, National Research Council, Washington, DC.
- Parnell, C. B., E. R. Emino, and E. K. Grubaugh. 1980. Cotton gin trash: Can it be safely utilized?. *Agric. Eng.* 61: 21-22.
- Parnell, C. B., Jr., E. P. Columbus, and W. D. Mayfield. 1994. Abatement of air pollution and disposal of gin waste. In: W. S. Anthony and W. D. Mayfield (eds.) *Cotton Ginners Handbook*. p 172-194.
- Pons, W. A., Jr., C. L. Hoffpauir, and T. H. Hooper. 1953. Gossypol in cottonseed: Influence of variety of cottonseed and environment. *J. Agric. Food. Chem.* 1: 1115.
- Poore, M. H. 1994. Whole cottonseed in sorghum-silage based diets for developing heifers. *J. Anim. Sci.* 72: 382.
- Poore, M. H., and G. Rogers. 1995. Feeding whole cottonseed and other cotton by-products to beef cattle. *Vet. Med.* 90: 1077-1087.
- Pordesimo, L. O., S. J. Ray, M. J. Buschermohle, J. C. Waller, and J. B. Wilkerson. 2005. Processing cotton gin trash to enhance *in vitro* dry matter digestibility in reduced time. *Bioresour. Technol.* 96: 47-53.
- Preston, R. L. 2006. 2006 Feed Composition Tables. *BEEF Magazine*: 50-66.
- Prevatt, W., D. Rankins, M. Davis, D. Ball, and J. Stanford. 2005. Alabama fall stocker budgets, 2005-2006. *Alabama Ext. Sys. Bulletin AEC BUD 1-4*.
- Randel, R. D., C. C. Chase, Jr., and S. J. Wyse. 1992. Effects of gossypol and cottonseed products on reproduction of mammals. *J. Anim. Sci.* 70: 1628-1638.
- Rankins, D. L., Jr. 2002. Importance of by-products to the United States beef industry. *Vet. Clin. Food Anim.* 18: 207-211.
- Rankins, D. L., Jr. 2004. By-product feeds for Alabama beef cattle. *Alabama Ext. Sys. Bulletin ANR-1237*.
- Rankins, D. L., Jr., and B. E. Gamble. 2000. Evaluation of various by-products for use in stocker cattle diets. *J. Anim. Sci.* 78 (Suppl. 1): 284.

- Reddell, D. L., C. B. Parnell, Jr., T. Marek, and D. Hansford. 1975. Composting cotton gin trash. Texas Agric. Exp. Sta., Texas A & M University, 8 pp.
- Reeves, B. G. 1976. State of the art in gin trash disposal. USDA/Economic Research Service, 5 pp.
- Reiser, R., and H. C. Fu. 1962. The mechanism of gossypol detoxification by ruminant animals. *J. Nutr.* 76: 215-218.
- Rogers, G. M., and M. H. Poore. 1994. Alternative feeds for reducing beef cow feed costs. *Vet. Med.* 89: 1073-1084.
- Rogers, G. M., and M. H. Poore. 1995. Optimal feeding management of gossypol-containing diets for beef cattle. *Vet. Med.* 90: 994-1005.
- Rogers, G. M., M. H. Poore, and J. C. Paschal. 2002. Feeding cotton products to cattle. *Vet. Clin. Food Anim.* 18: 267-294.
- Sagebiel, J. A., and N. Cisse. 1984. Feeding cotton gin trash to wintering pregnant beef cows. In: *Proc. West. Sec. Am. Soc. Anim. Sci.* p 130-133.
- Schingoethe, D. J. 1991. By-product feeds: Feed analysis and interpretation. *Vet. Clin. Food Anim.* 7: 577-584.
- Seiber, J. N., R. G. Curley, D. J. Hills, O. D. McCutcheon, G. E. Miller, G. S. Pettygrove, and W. L. Winterlin. 1982. Summary and evaluation. In: *Final Report, Utilization of Cotton Gin Wastes-Technology Demonstration and Safety Testing of Composting and Evaluation of Alternate Utilization Strategies*, University of California at Davis, 6 pp.
- Seiber, J. N., W. L. Winterlin, and M. M. McChesney. 1979. Residues of toxaphene, DEF, and paraquat in plant parts and gin waste from a treated cotton field. *Arch. Environm. Contam. Toxicol.* 8: 125-137.
- Smith, C. W., R. G. Cantrell, H. S. Moser, and S. R. Oakley. 1999. History of cultivar development in the United States. In: C. W. Smith and J. T. Cothren (eds.) *Cotton: Origin, History, Technology, and Production*. p 99-171. John Wiley & Sons, Inc.
- Smith, G. S., and A. B. Nelson. 1975. Effects of sodium silicate added to rumen cultures on forage digestion, with interactions of glucose, urea, and minerals. *J. Anim. Sci.* 41: 891-899.
- Speth, C. F., V. R. Bohman, H. Melendy, and M. A. Wade. 1962. Effect of dietary supplements on cows on a semi-desert range. *J. Anim. Sci.* 21: 444-448.

- Stewart, R. L., M. J. Bader, and G. H. Harris. 1998. The evaluation of cotton gin trash as a cattle feed. University of Georgia, Animal & Dairy Science Annual Report.
- Swingle, R. S. 1995. Effect of roughage level and type on intake and performance of feedlot cattle. In: Symposium proceedings: Intake by Feedlot Cattle, Stillwater, OK: Okla. Agric. Exp. Sta. Bull. P-942: 257.
- Thomasson, J. A. 1990. A review of cotton gin trash disposal and utilization. In: Beltwide Cotton Production Research Proceedings, Las Vegas, NV. p 689-705.
- Thomasson, J. A., W. S. Anthony, and E. P. Columbus. 1991. Survey of cotton gin trash disposal practices and preferences in the Midsouth. In: Beltwide Cotton Production Research Proceedings. p 993-996.
- Thomasson, J. A., W. S. Anthony, J. R. Williford, W. H. Johnson, S. R. Gregory, M. C. Calhoun, and R. L. Stewart. 1998. Processing cottonseed and gin waste together to produce a livestock feed. In: Beltwide Cotton Production Research Proceedings, San Diego, CA. p 1695-1698.
- Utley, P. R., R. S. Lowrey, and W. C. McCormick. 1973. Types of roughage and intermittent changes of roughage types in beef cattle finishing diets. *J. Anim. Sci.* 37: 395-398.
- Utley, P. R., R. S. Lowrey, and W. C. McCormick. 1974. Peanut hulls as a source of roughage in cattle finishing diets. University of Georgia College of Agriculture, Coastal Plain Station, Tifton Research Bulletin 154.
- Utley, P. R., and W. C. McCormick. 1972. Level of peanut hulls as a roughage source in beef cattle finishing diets. *J. Anim. Sci.* 34: 146-151.
- Van Soest, P. J. 1994. Pages 138-139 in *Nutritional Ecology of the Ruminant*. Cornell University Press, Ithaca, NY.
- Van Soest, P. J., J. B. Robertson, and B. A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *J. Dairy Sci.* 74: 3583-3597.
- Wakelyn, P. J., C. A. O'Brien, and H. Lowenschuss. 1972. Cotton gin trash as animal feed: Presence of aflatoxin. *Southwest. Vet.*: 293-298.
- Waller, J. C. 2006. By-products and unusual feedstuffs. *Feedstuffs Reference Issue and Buyer's Guide* 77: 18-22.
- Whiting, F. M., and J. D. Schuh. 1988. Use of cotton gin trash in the diets of growing dairy heifers. In: *Proc. West. Sec. Am. Soc. Anim. Sci.* p 399-401.

Williford, J. R., A. D. Brashears, and G. L. Barker. 1994. Harvesting. In: W. S. Anthony and W. D. Mayfield (eds.) Cotton Ginners Handbook. p 11-16.