VARIOUS PARAMETERS OF COTTON GIN BYPRODUCTS PRODUCED FROM THE GIN PROCESSING MACHINERY

G. A. Holt, G. L. Barker, R. V. Baker and A. Brashears
USDA ARS
Cotton Harvesting and Ginning Research Laboratory
Lubbock, TX

Abstract

The byproducts produced by the cotton ginning process have commonly been referred to as cotton gin trash or waste because of the costs associated with their disposal and their limited value in current utilization applications. However, cotton gin byproducts (CGB) have been the subject of extensive research and have found some limited applications as a roughage in livestock feed, compost material, and as a soil amendment. Typically, all research pertaining to utilization of CGB has evaluated or measured some aspect of the product to determine a desired or needed characteristic pertaining to a specific objective or goal. Cotton gins produce various streams of byproducts due to the design and layout of the equipment used in the cotton ginning process. Historically, the byproducts from the different gin processes are combined into a single waste stream and conveyed to a central location. The objective of this research was to characterize the various parameters of the byproducts coming from the individual waste streams prior to being combined to ascertain if the ginning equipment was sorting the byproducts into components that had more desirable characteristics to potential end users. Results indicated that the extractors along with the lower gin motes, gin stand feeder, overflow separator and lint cleaners produced a product with more desirable characteristics for livestock feeding and fuel utilization than those byproducts from the inclined cleaners and unloading system.

Introduction

An economical and efficient means of disposing of cotton gin trash (CGT) has been a topic of research for years. One of the most economical means of disposal is to find a market for the estimated 2.25 million tons of gin trash being generated each year across the cotton belt of the United States (calculated from data in 1997 Census of Agriculture). Over the years, extensive research has been performed to evaluate the usefulness and feasibility of using CGT for various applications including fire logs (Karpiscak et al., 1982), an energy source (Beck and Clements, 1982; Lacewell et al., 1982; Parnell et al., 1991 ; White et al. 1996)), livestock feed (Holloway et al., 1974; Conner and Richardson, 1987; Poore and Rogers, 1995), raw materials in asphalt roofing products (Kolarik and Smith, 1978), and compost (Hills, 1982; Shumack et al., 1991; Truhett, 1994, Ayers, 1997). The amount of research that has been performed on this subject is far more extensive than indicated in the few examples above. For a more thorough overview of previous research efforts, refer to Thomasson, 1990. Despite extensive research efforts, very few uses for CGT ever reached widespread commercial acceptance. The most successful applications involve using CGT in livestock rations and in producing compost. Today, much of the available CGT is still disposed of by returning it back to the originating crop land. These applications, while successful in numerous localized situations, utilize only a small portion of the available CGT.

One of the primary obstacles that needs to be resolved in the area of CGT utilization is the terminology. The term "trash" has been used extensively for many years because the byproducts of the ginning operation were not considered to have monetary value and were, for the most part, unwanted waste that created a disposal problem. However, not all CGT is trash (Price, 1982) and the byproducts of the ginning operation have useful characteristics which can be exploited to produce a number of valuable products. In recognition of this potential, throughout the remainder of this paper the term Cotton Gin Byproducts (CGB) will be used in lieu of CGT.

Another obstacle to more complete utilization of CGB is the issue of "cleanliness". CGB by their very nature contain varying amounts of sand and dirt depending on the crops geographical location, method of harvest, and other factors. The idea of cleaning/screening the CGB to remove the sand and dirt in an effort to enhance its value has been a point of emphasis in studies throughout the literature (Young and Griffith, 1976; Kolarik et al., 1978; and Axe et al., 1982). As stated in Kolarik et al., 1978, the most opportune place to remove dirt and sand is in the pre-cleaning stages at the cotton gin. However, it is common practice at most cotton gins, to combine all the waste product generated from the various pieces of equipment in the ginning process and send the collective lot to the bur house. This process has led to CGB being evaluated on a collective or bulk basis instead of an individual "as generated" basis.

Most of the research studies that have been performed to evaluate the potential end use value of CGB have involved only a narrow set of parameters that were critical to the particular end use in question. Consequently, the characteristics that have been studied have varied considerably from one research study to another. Generally, fuel properties, feeding values, chemical residues, and particle size distribution of bulk CGB are the characteristics which are most often reported.

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Objective

The objective of this research was to measure and quantify the characteristics of CGB generated from various equipment in the ginning operation and to document the characteristics of each major source of CGB before it is mixed in the bur hopper. This research was undertaken in the belief that "gin trash", as it is currently thought of can be redefined from "trash" to "useful waste" or "cotton gin byproducts". The data obtained from this research should provide potential end users with information that will help promote the use of CGB as an economical and effective product that can met their specific feeding, fuel, or raw material needs.

Equipment and Procedures

System Layout and Sample Locations

Figure 1 shows a schematic of the flow diagram for the gin at the USDA-ARS ginning laboratory in Lubbock, TX. The ginning system is designed for stripper harvested cotton. CGB samples were obtained from ten locations in the ginning process. Each sample was collected either from the machine itself or from the discharge of the trash collection cyclones associated with that portion of the process. The ten sampling locations were: 1) Unloading system cyclone, 2) No. 1 pull fan cyclone, 3) No. 2 pull fan cyclone, 4) 1st stage extractor, 5) 2nd stage extractor, 6) Distributing conveyor separator cyclone, 7) Overflow separator cyclone, 8) Feeder trash cyclone, 9) Gin stand lower moting system, and 10) Lint cleaner waste collectors (mote condenser). Due to the small quantity of CGB that was produced from some of the equipment listed above, several samples from similar sources were combined in order to obtain enough material to perform all the analyses desired. For example, the samples from both pull fan cyclones were combined to represent waste from air-fed inclined cleaners. Other combined samples included the waste from the two bur and stick extractors, the material collected at sampling locations 6-9, and the waste from both saw-type lint cleaners. These four combined samples and the original unloading system sample produced a set of samples representing waste from, what is referenced in the remainder of the paper, as the five equipment categories: 1) Unloading System, 2) Feeder & Gin Stand, 3) Inclines, 4) Extractors, and 5) Lint Cleaners. These equipment categories are numbered one through five in Figure 1.

Procedure

CGB samples were obtained for two stripper cotton varieties (Paymaster HS 26 and HS 200). The varieties chosen were the two most commonly used varieties in the Texas South Plains production area. The two varieties were grown during crop year 1998 in two separate fields. Both varieties were harvested with and without field cleaning, thus producing four batches of test cotton (HS 26 with and without field cleaning, HS 200 with and without field cleaning). An individual sample (referred to as a bale sample) consisted of collecting all the byproducts produced from ginning one bale of cotton. A minimum of three bales (replications) of CGB were collected for each of the four test cottons.

The bale samples were collected in metal containers at the locations previously listed. Catching the discharge from each cyclone was made possible by the installation of Y-valves between the trash auger and the cyclone. For each category, a sample size of approximately 50 lbs was set as the desired quantity since it was determined to be the amount needed to a perform all the analyses and still have some reserve. Therefore, after ginning a bale of cotton, the amount of CGB produced from all sample locations was weighed and then a sub sample of 15 to 20 lbs was retained and combined into the appropriate equipment category and the remainder of the waste discarded. Thus, the three samples obtained after each bale were combined into one 50 to 60 lb "equipment category sample". This same procedure was repeated for each test cotton and harvest method.

Analysis

The following parameters/characteristics were chosen as potentially important and measured for each of the samples in each equipment category: 1) Density (particle and bulk), 2) Durability, 3) Particle size distribution (sieve analysis), 4) Angle of repose, 5) Heating value (gross and net), 6) Proximate analysis (moisture, ash, volatile matter, fixed carbon), 7) Ultimate analysis (C, N, S, O), 8) Fusion temperature, 9) Metals (Fe, As, Hg, B), 10) Minerals (P, K, Ca, Mg, Mn, Na, Zn, Mo, Cu), 11) Forage analysis (Crude Protein (CP), Crude Fat (CF), Soluble Protein (SP), Adjusted Crude Protein (ACP), Dry Matter (DM), Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), Available Protein (AP), Unavailable Protein (UAP), Non Structural Carbohydrates (NSC), Total Digestible Nutrients (TDN), Net Energy Lactation (Nel), Net Energy Maintenance (Nem), Net Energy Gain (Neg), Lignin, pH), and 11) Chemical residues (Paraquat, Trifluralin, Aldicarb, Ethephon, Prometryn, Dimethoate, Oxamyl, Lambda-cyhalothrin, Permethrin, Dicrotophos, Thidiazuron). The measurement of moisture, sulfur, and ash contents were performed by both a forage lab and a fuel analysis lab. The test methods used by these two labs for these measurements varied according to common practices and procedures used in their respective fields (i.e. the fuel lab used ASTM methods most commonly used for analysis of coal whereas the forage lab used methods commonly associated with feed analyses). The analytical methods used to obtain the parameters listed in this report are listed in Table 1. For characteristics not listed, the value was obtained by using results either from one or several methods to calculate the value. For example, Non-Structural Carbohydrates (NSC) was calculated from subtracting the sum of crude protein (CP), crude fat (CF), ash, and neutral detergent fiber (NDF) from 100 plus unavailable protein (UAP).

The Durability test was conducted using a modification of ASAE Standard S269.4 (ASAE Standards, 1998). The Durability measurements were performed in conjunction with the Particle Size Distribution measurements. For particle distribution, nine sieves were used. Sieve sizes included: 1) 7/8 in., 2) 3/4 in., 3) 5/8 in., 4) 3/8 in., 5) 5/16 in., 6) 1/18 in., 7) 1/32 in., 8) 1/140 in., and 9) 1/318 in. followed by a pan. After sieving 0.13 lbs of each CGB sample from the five equipment categories for 10 minutes, the quantity of CGB that remained in the 7/8 in. sieve was tumbled in a device meeting the specification of the durability tester for pellets and crumbles in the ASAE Standard. The samples were tumbled for 10 minutes and then sieved again using the 7/8 in., 1/18 in., 1/32 in., 1/140 in., and 1/318 in. sieves. The smaller size sieves were used since it was believed that after the tumbling only the smaller size particles would be the ones separated from any lint in the larger sieve. The quantity collected by each sieve was weighed, recorded, and the procedure repeated twice for all CGB samples.

The chemical residue tests were limited to the chemicals used on each test cotton during the season, from planting to harvest. The HS 26 variety was grown using the chemicals Paraquat, Trifluralin, Ethephon, Thidiazuron and Aldicarb. Whereas the HS 200 variety was grown using all the chemicals listed in item 11 above with the exception of Paraquat, Aldicarb, and Ethephon. Due to unforeseen difficulties, none of the samples were analyzed for Thidiazuron.

For the analyses, a 1 lb sub-sample from each equipment category was placed in a plastic sealable bag. The size of the sub-samples was based on the average quantity needed by the individual laboratories for the specified analyses. A total of six labs were used to collect the data for this research. One lab performed all the feeding analysis work (items 9 and 10 above). Two labs were used for measuring the chemical residues. Another lab evaluated the particle density while the last two labs were used for all the combustion/fuel analyses. The remaining analyses of bulk density, durability, angle of repose, and particle size distribution were conducted in-house. For the chemical residues and combustion/fuel analyses, each lab measured different parameters or evaluated different chemicals thus there are no duplicate measurements between labs. The labs used are not listed since these methods are not exclusive to those labs. The methods can be performed by any analytical lab setup for the analyses in question.

Evaluation

The results from all the analyses were analyzed using a General Linear Model (GLM) analysis of variance (ANOVA) performed using SAS statistical software (Freund et al., 1986). The three factorial analysis was performed on the average results obtained for each sample in each of the five equipment categories. The results from the ANOVA were evaluated to determine the grouping of the data. For example, should the results for Crude Protein (CP) be averaged for each category, each variety, the different harvesting methods, or should they be reported individually. The main effects evaluated were location (in the gin), harvest method, and variety. However, for this particular research the term variety should be used synonymously with field since the varieties were not grown in the same plots of land under the same conditions. Therefore a significant difference in “variety” could easily indicate differences in fertilizers, water supply, soil conditions and other items as well. The statistical analysis was performed for all the parameters except particle size distribution, which was not suitable for this type of analysis.

The mean data for the parameters was used in the analysis since all labs did not report each individual test, but rather the average results. The three way interaction of location by variety by harvest method was used as the error term.

The statistical analysis for the chemical residues was performed for location and harvest since Variety (field) was not a factor as a result of each field having had different chemicals applied to the crop during the growing season. The GLM for the chemical residue was performed to ascertain level of significance between location and harvest method.

Results

The average weight of CGB produced from each equipment category for each variety is shown in Table 2. The data in Table 3 represents the percent of mass collected for each equipment location. The results show that between 6.5 to 11% of the CGB came from the unloading system, 2 to 6% from the Feeder & Gin Stand category, 13.5 to 20% from the inclined cleaners, 50.5 to 72% from the extractors, and 5 to 12% from the lint cleaners. In Table 2, the “Lower Gin Motes” value of 9.8 lbs is higher than the other values due to excess motes that were being generated due to a clogged mote board. Adjustments to correct the problem were made after two bales of the HS26 field cleaned seed cotton had been ginned, which is why the other samples show smaller Lower Gin Motes averages.

Table 4 shows the results for the parameters that indicated test cotton as the source of significance at the 0.05 level. Values in the table with the same letter were not statistically different. It should be noted that the results in Table 4 are for reporting purposes only and do not imply that variety is the basis for the statistical difference. For a true assessment of variety, various varieties should be grown under identical conditions and then evaluated to see if parameters show significance based on variety. Since this data was not collected in that manner, the values in Table 4 are more likely the result of different growing conditions than they are of variety. The significance indicated by the statistical analysis is more an indication that, for these samples, gin equipment and harvest method were not of significance.

Table 5 shows the results for samples that indicated Gin Equipment as the source of significance at the 0.05 level. The Durability parameter is an indicator of the percent of a given material that will remain intact after being tumbled for 10 minutes. The value in the table indicates the percent of the initial mass that remained on the 7/8 in. sieve after being tumbled. Durability results indicate that any mass large enough to stay on the largest sieve after the initial sieving will retain from 55 to 95 % of the same mass after undergoing rigorous "handling". The Feeder & Gin Stand equipment category yielded the lowest durability with 54.9% while the Lint Cleaners (motes) yielded the highest with 95.2 % durability.

The particle density parameter is defined as the bulk density minus the void spaces. Due to the wide range of particle sizes that come from various machinery, this value could vary according to an individual gins process flow as well as the location of that machine in the gins machinery sequence. Even so, the particle density was measured to obtain an average density for the equipment in use. Analysis for particle density was performed using a gas pycnometer with nitrogen as the gas.

Table 6 shows the mean parameter values for angle of repose along with four fusion temperatures; 1) initial deformation, 2) softening temperature, 3) hemispherical temperature, and 4) fluid temperature. The values in this table indicated an interaction between gin equipment and either harvest method or variety (field). In the case of the fusion temperatures, the interaction involved variety (field) whereas the angle of repose showed an interaction with harvest method. The mean values are listed by gin equipment for reference. More data would need to be collected in order to further evaluate the level of interaction. It should be noted that the fusion temperatures measured by ASTM D 1857, Standard Test Method for Fusibility of Coal and Coke Ash may have deformation temperatures below those indicated by the ASTM cone test. In some cases the temperature may be several hundred degrees lower than that indicated by the ASTM cone test. (Jenkins, 1993). A suggested list of selected analytical methods for determining physical properties of biomass can be found in (Jenkins, 1993 and Jenkins et al. 1998).

Table 7 contains the mean values for all parameters that did not indicate a 0.05 level of significance for either equipment category, harvest method, or test cotton. These values are for reporting purposes only and are not intended to imply levels of significance for gin equipment location in regards to these parameters. Failing to indicate a level of significance would indicate that there is not sufficient evidence, based on these samples, to reject the hypothesis that all the means are equal, at least at the 95% confidence level. To ascertain if these parameters could be divided into categories based on processing equipment, growing habits, harvest method, or variety would require collecting more data.

Table 8 contains parameters that did not exhibit any measurable values. The values in Table 8 are below the minimum detection limits (MDL) of the analysis procedures used in the lab and therefore could be any value in between the MDL and zero, including zero. There is one exception listed in Table 8. A value of 1.7 ppm, for lead, was recorded for a non field cleaned, HS 200 sample from the inclined cleaners. All other lead samples analyzed were below the MDL. A possible explanation for the outlier could have been some metal originating from the processing equipment.

Figures 2 through 6 show bar graphs for the particle size distribution for the field cleaned and non-field cleaned data on an equipment basis. The figures contain the average percent of mass retained for each sieve along with the standard error. As can be seen from the figures, the standard error was rather large for some of the sieves. Variation between the field cleaned and non-field cleaned samples is best illustrated in figure 2 where the field cleaned samples show a larger amount being retained on the 7/8 in. sieve in comparison to the non-field cleaned samples. This was the result of more lint being in the field cleaned samples, collected from the unloading system, than was in the non-field cleaned samples. In some cases, figure 6 for example, 92 to 97% of the sample was collected in the top sieve and the particles that were collected in the other sieves were those particles that were shaken loose from the lint during the sieving. Overall, the bulk of the mass was accumulated on different sieves for different equipment categories. Using the overall average of all the samples analyzed on an equipment category basis, the sieve accumulating the largest average percent of mass was: 1) Unloading System - pan (19 %), 2) Feeder & Gin Stand - 1/18 in. (36.5 %), 3) Inclines - 1/140 in. (26 %), 4) Extractors - 3/8 in.(46.4 %), and 5) Lint Cleaners - 7/8 in. (95.5 %). Summing the averages for all the percent mass collected on all the sieves below the 1/18 in. sieve, for each equipment category, showed the following: 1) Unloading System - 67 %, 2) Feeder & Gin Stand - 17.8 %, 3) Inclines - 57.5 %, 4) Extractors - 2.5 %, and 5) Lint Cleaners - 3.4 %. Thus the unloading system and inclined cleaner samples had a majority of their mass smaller than 1/18 inch in size.

Summary

Much of the CGB produced by the cotton ginning process have commonly been disposed of as a waste product. Many of these disposal methods have come under regulatory and economic scrutiny. With larger cotton crops and fewer gin facilities, there is a critical need for finding more economical and effective ways to utilize CGB. Extensive CGB research shows great promise, in terms of potential new uses. In the past, one of the primary means of surveying CGB was to collect a sufficient sample(s) from the bur hopper. The bur hopper is the place where all the CGB are stored before disposal. Usually there was some aspects of the waste that were not desirable and a means of "cleaning" the waste was sought. In a number of cases, one of the least desirable elements of the CGB was the sand in addition to other things, depending on the final use. Since the normal operation of a gin is designed to clean the seed cotton (and lint) in a "progressive" fashion starting with the coarser and more abrasive foreign matter and finishing with the finer less abrasive foreign matter, it is logical to collect only waste from the area or equipment producing the product of interest.

The focus of this research was to give insight into an extensive list of parameters of CGB, for stripper harvested varieties, as they are being generated in the ginning process prior to being combined in the bur hopper. This was undertaken in the hopes that if not all the product could be effectively utilized, then at least most or some could be and that the gin, by design, has some equipment or areas that produce a more desirable product than other areas of the gin. The results indicate that the Feeder & Gin Stand, Extractors, and Lint Cleaner categories produce a cleaner more appealing product, for use in livestock feed or fuel, than does the Unloading System and Inclines. The Lint Cleaners produce fiber that exhibits some favorable properties when compared to other equipment. However, in most places, the motes produced from the lint cleaners have a market that generates revenue. In areas where motes are not collected or there is not a market for motes, the Feeder & Gin Stand, Extractors and Lint Cleaners equipment categories could be combined to account for up to 64 to 80% of the waste having properties that could attract potential end users. Overall, the results indicate that keeping the waste streams separate can result in a more desirable by-product that may have more economic value than the combined total.

Some of these characteristics will change according to the amount of rainfall/irrigation, fertilizers applied, soil conditions/type, quantity and type of chemicals used, location of the country, and a variety of other factors too numerous to list. Additional data is needed to further define distinctions that may exist based on variety, harvest method, or equipment and to quantify those differences. To obtain reliable averages for the items of greatest interest, a sufficient number of samples need to be collected for a given variety, harvest method, and gin layout. One facet of more effective and efficient use of CGB is having a mind set that it is a product of value, and not trash. Very few end users want to use "trash".

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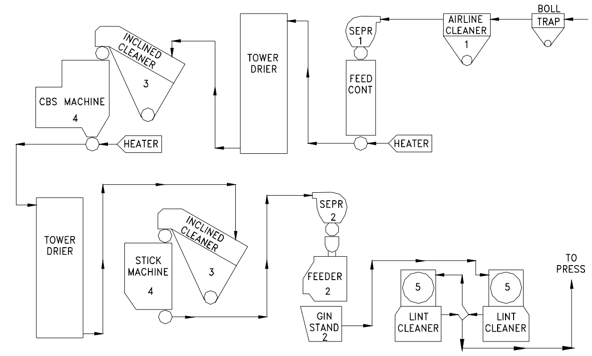

Figure 1. Schematic diagram of the machinery layout used at the Lubbock, TX USDA-ARS gin lab specifying the five equipment categories of 1) Unloading System, 2) Feeder & Gin Stand, 3) Inclines, 4) Extractors, and 5) Lint Cleaners.

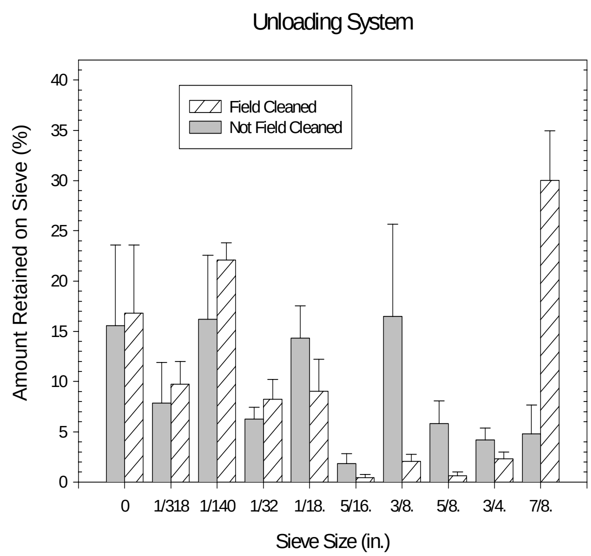

Figure 2. Average percent retained on each sieve for both field cleaned and non-field cleaned samples from the unloading system shown with standard error bars.

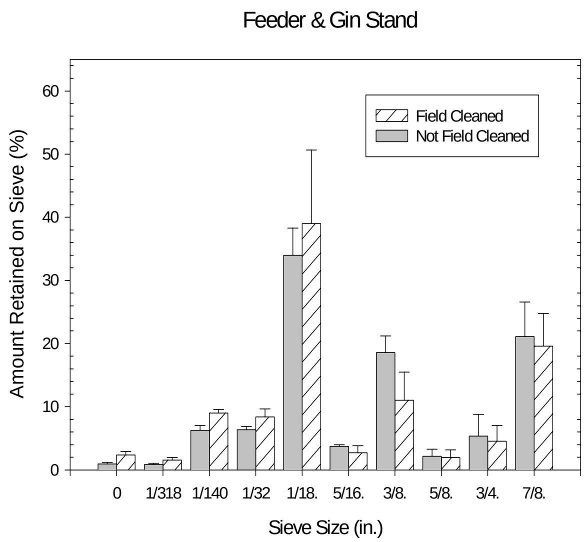

Figure 3. Average percent retained on each sieve for both field cleaned and non-field cleaned samples from the feeder and gin stand shown with standard error bars.

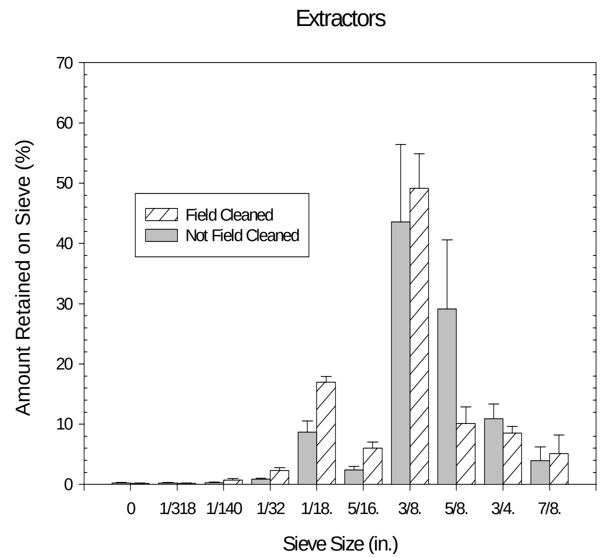

Figure 5. Average percent retained on each sieve for both field cleaned and non-field cleaned samples from the extractors shown with standard error bars.

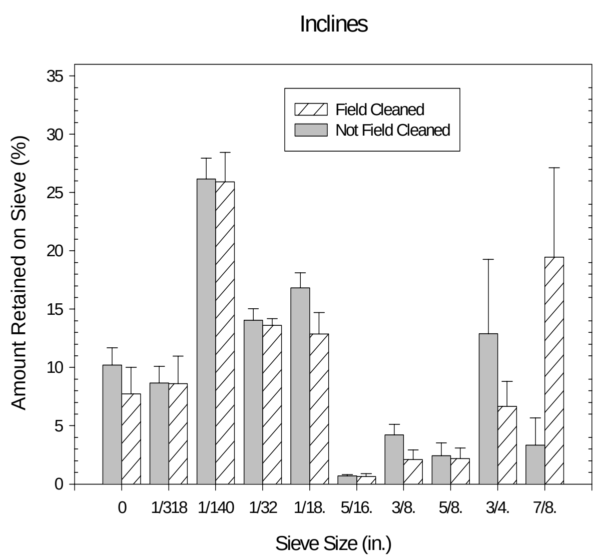

Figure 4. Average percent retained on each sieve for both field cleaned and non-field cleaned samples from the inclined cleaners shown with standard error bars.

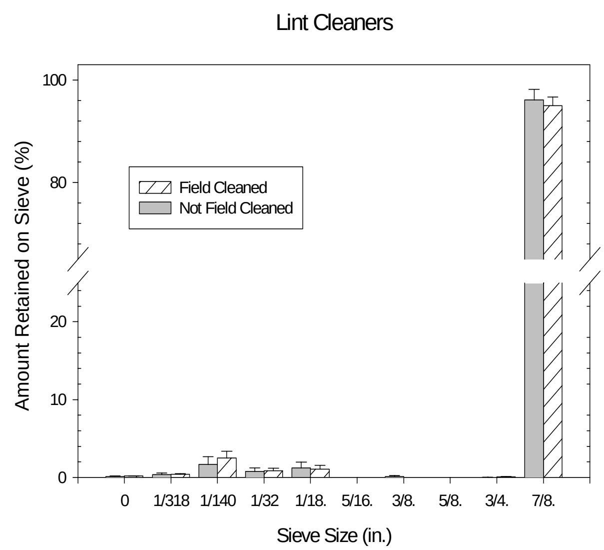

Figure 6. Average percent retained on each sieve for both field cleaned and non-field cleaned samples from the lint cleaners shown with standard error bars.

Table 1. Analytical methods and references used to obtain results presented for the various parameters and characteristics measured.

Parameter(s) Analyzed	Method of Analysis or Reference/Equipment
Fuel Properties	
Proximate Analysis	ASTM D 5142*
Ultimate Analysis	ASTM D 3176
Fusion Temperatures	ASTM D 1857
Volatile Matter, Ash, Moisture	ASTM D 5142
Sulfur	ASTM D 3177
Heating Value	ASTM D 2015
Metals & Chemical Residues	
Boron & Lead	SW 846 - 6010B §
Mercury	SW 846 - 3010A & 7471A
Arsenic	AOAC¥. 1975. 12th ed. Section 25.006
Paraquat	Southern Testing & Research Labs, Inc. method # AR-AG210
Ethephon	Journal of AOAC. 1976. vol. 59(3) pg. 617-621
Other Chemical Residuals	Luke Procedure - P.A.M. 1983. Vol. 1 Extraction 4
Feeding Properties	
Dry Matter	AOAC 930.15
Crude Protein	AOAC 976.06 (G), (H)
Soluble Protein	Cornell Sodium Borate-Sodium Phosphate Buffer Procedure
Unavailable Protein	NIRS - ADI-CP
NDF, ADF, & Lignin	ANKOM A200 Filter Bag Technique (FBT)
Minerals	Thermo Jarrell Ash "The Spectroscopist" Dec. 1994, vol 3. No.1-ICP
Chloride Ion	Potentiometric titration with $AgNO_3$
Sulfur	Leco Model SC-432
Crude Fat	Ether Extract - Tecator Soxtec System HT6
Ash	AOAC 942.05
pH	pH/ion meter
Net Energies	Bill Weiss - Ohio State University method

* American Society for Testing and Materials (ASTM)

§ *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods* (SW 846 from the U.S. EPA Office of Solid Waste).

¥ Association of Official Analytical Chemist (AOAC)

Table 2. Average weight of cotton gin byproducts generated from each location by test cotton and harvest method.

Sampling Locations	HS 26 Field Cleaned lbs/bale	HS 26 Not Field Cleaned lbs/bale	HS 200 Field Cleaned lbs/bale	HS 200 Not Field Cleaned lbs/bale
Suction	33.7	50.5	24.5	40.0
Unloading System Total	33.7	50.5	24.5	40.0
#6 Seperator	2.1	1.5	0.1	1.1
Overflow	0.6	0.2	0.0	0.0
Feeder Trash	7.0	17.0	2.5	10.0
Lower Gin Motes	9.8	2.8	1.8	2.7
Feeder & Gin Stand Total	19.5	21.5	4.4	13.7
#1 Inclined Cleaner	46.3	74.0	52.0	65.5
#2 Inclined Cleaner	15.0	22.0	12.5	19.0
Inclines Total	61.3	96.0	64.5	84.5
1st Extractor	130.1	416.6	108.5	389.0
2nd Extractor	33.4	89.0	18.0	57.5
Extractors Total	163.4	505.6	126.5	446.5
Lint Cleaner 1	25.1	28.8	24.8	26.8
Lint Cleaner 2	5.6	6.6	5.7	6.7
Lint Cleaners Total	30.8	35.4	30.5	33.5
Total	308.7	708.9	250.4	618.2

Table 3. Percent of cotton gin byproducts produced by test cotton and harvest method per equipment category.

Equipment Category	HS 26 Field Cleaned (% of total)	HS 26 Not Field Cleaned (% of total)	HS 200 Field Cleaned (% of total)	HS 200 Not Field Cleaned (% of total)
Unloading System	10.9	7.1	9.8	6.5
Feeder & Gin Stand	6.3	3.0	1.8	2.2
Inclines	19.9	13.6	25.8	13.7
Extractors	52.9	71.3	50.5	72.2
Lint Cleaners	10.0	5.0	12.1	5.4

Table 4. Mean parameter values of CGB with test cotton (field) being the source of significance.

Parameter Measured#	Units	Test Cotton Variety (field) HS 26	HS 200
Moisture Content	%	11.43a‡	8.3b
pH	--	6.11b	6.78a
Dry Matter	%	88.6b	91.7a
Unavailable Protein	%	2.12b	2.88a
Copper	ppm	6.1a	2.7b
Soluble Protein	%	43.8a	21.8b
Chloride Ion	%	0.87a	0.33b
Lignin	%	8.93b	13.8a
Sulfur	%	0.40a	0.15b

All values in the table were obtained from the forage analytical methods.

‡ Means followed by the same letter are not statistically different at the 0.05 level of significance.

Table 5. Mean parameter values of CGB with gin equipment being the source of significance.

Parameter Measured	Units	Gin Equipment: Unloading System	Feeder & Gin Stand	Inclines	Extractors	Lint Cleaners
Particle Density	lbs/in³	0.057a‡	0.043c	0.048bc	0.033d	0.052ab
Bulk Density 1*	lbs/ft³	13.27a	7.68ab	4.34b	5.74b	5.10b
Bulk Density 2§	lbs/ft³	20.39a	12.02ab	6.84b	7.93b	7.54b
Durability	%	89.4ab	54.9b	81.4ab	82.9ab	95.2a
Fuel Analytical Methods						
Heating Value (gross)	Btu/lb	6070b	7576a	6961ab	7120ab	7460a
Heating Value (net)	Btu/lb	5618b	6853a	6373ab	6395ab	6928a
Volatile Matter	%	51.4b	63.5a	58.7ab	63.6a	61.3ab
Fixed Carbon	%	12.6c	27.8ab	19.9bc	28.7ab	32.6a
Sulfur	%	0.34ab	0.26ab	0.42a	0.19b	0.18b
Moisture Content	%	7.67c	9.82ab	8.30bc	10.6a	6.87c
Ash	%	36.0a	8.73bc	21.4b	7.80c	6.17c
Carbon	%	34.5c	45.8ab	40.8b	46.6a	45.5ab
Oxygen	%	24.0c	39.2ab	31.3bc	39.6ab	41.6a
Mercury	ppm	0.164a	0.110ab	0.049b	0.044b	0.028b
Forage Analytical Methodology						
Ash	%	37.0a	11.5bc	27.1ab	8.63c	9.99bc
Crude Fat	%	3.55ab	5.38a	3.72ab	3.03ab	1.85b
Mag-nesium	%	0.34ab	0.33ab	0.39a	0.26b	0.28ab
Calcium	%	1.66ab	1.27ab	2.09a	0.97b	1.38ab
Potassium	%	1.34c	1.99b	1.69bc	2.54a	1.52c
Moly-bdenum	ppm	6.20a	2.35bc	3.83b	1.43c	1.45c
Manganese	ppm	97.0a	46.0bc	73.5ab	28.5c	37.7c
Iron	ppm	3860a	1011b	1791b	214b	261b
Net Energy Lactation	%	0.31b	0.51a	0.37ab	0.46ab	0.47ab
Net Energy Main-tenance	%	0.16b	0.45a	0.24ab	0.38ab	0.39ab
NSC+	%	0.10b	16.8ab	9.78ab	21.7a	16.4ab
TDN+	%	32.5b	48.3a	36.8ab	45.2ab	46.5ab

‡ Means followed by the same letter are not statistically different at the 0.05 level of significance.

* Bulk density value is from loosely filling a container and leveling off the top - loose fill.

§ Bulk density value is from hand packing the product into a container - hand packed.

+ Non Structural Carbohydrates (NSC), Total Digestible Nutrients (TDN).

Table 6. Mean parameter values of CGB with gin equipment being the source of significance and indicating an interaction with either harvest method or variety (field).

Parameter Measured	Units	Gin Equipment: Unloading System	Feeder & Gin Stand	Inclines	Extractors	Lint Cleaners
Angle of Repose*	deg.§	38.8ab ‡	39.0ab	38.3b	46.0a	42.3ab
Fusion Tempera-tures+	°F					
Initial Deformation		2336cd	2397bc	2243d	2524ab	2551a
Softening		2354b	2425ab	2314b	2546a	2585a
Hemis-pherical		2377b	2433b	2362b	2585a	2599a
Fluid		2421b	2455ab	2430ab	2599ab	2616a

* Angle of repose indicated a significant interaction between harvest method and gin equipment.

§ Units are in degrees.

‡ Means followed by the same letter are not statistically different at the 0.05 level of significance.

+ Fusion temperature showed significance between variety (field) and gin equipment.

Table 7. Mean parameter values of CGB that did not indicate a source of significance, at the 0.05 level, for any of the three dependent variables: gin equipment, harvest method, or test cotton (field).

Parameter Measured	Units	Gin Equipment: Unloading System	Feeder & Gin Stand	Inclines	Extractors	Lint Cleaners
Forage Analytical Methods						
Net Energy Gain	%	0.03	0.20	0.07	0.13	0.15
Acid Detergent Fiber	%	60.0	49.6	48.0	53.6	61.9
Adjusted Crude Protein	%	6.30	10.8	9.92	6.40	6.10
Available Protein	%	5.30	9.75	8.92	5.40	5.10
Crude Protein	%	7.88	12.2	11.6	7.90	7.35
Neutral Detergent Fiber	%	65.3	56.5	53.8	61.1	66.7
Zinc	ppm	52.5	88.3	35.3	11.8	21.5
Phosphorous	%	0.13	0.22	0.19	0.13	0.16
Fuel Analytical Methods						
Hydrogen	%	3.82	4.78	3.63	4.69	5.24
Nitrogen	%	1.28	1.25	1.49	1.10	1.25
Arsenic	ppm	0.80	0.32	0.36	MDL +	MDL

+ Value was below the minimum detection limit (MDL) of the analysis method. The MDL for Arsenic was 0.25 ppm.

Table 8. Lead and chemical residue values of CGB that were below the minimum detection limits (MDL) of the laboratory analysis methods used for their measurement.

Parameter Measured	Units	Minimum Detection Limit
Lead	ppm	0.5*
Dictrotophos	ppm	1.4
Oxamyl	ppm	0.003
Prometryn	ppm	0.4
Aldicarb	ppm	0.069
Trifluralin	ppm	0.01
Dimethoate	ppm	0.28

* All measurements were below the MDL except for a reading of 1.7 ppm from the inclines on the HS 200 non-field cleaned sample.