COMPARING ABRASIVENESS OF COTTON GIN BY-PRODUCTS USING THE COBY PROCESS

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Abstract

Abrasiveness of cotton gin by-products (CGB) is a major cost factor associated with processes designed to add value or handle them. Costs associated with CGB cleaning and equipment wear often times amount to half the cost of processing. A value-added process, known as the COBY process, developed at the Lubbock, TX USDA-ARS Cotton Ginning Laboratory showed signs of reducing the abrasiveness of CGB. In an effort to determine if and to what degree the abrasiveness was reduced, wear tests were performed using COBY process equipment. Reduction in CGB abrasiveness was evaluated using three different treatments. The treatments included applying: 1) 4% hot water, 2) a 4% gelatinized starch and hot water mixture, and 3) a 4% gelatinized starch and a 4% dry starch mixture (4%-4%). Results indicate that wear was significantly reduced, 27 to 29%, by adding gelatinized starch to the CGB being processed.

Introduction

Economically utilizing the 2.3 million plus tons of byproducts from cotton gins has been a topic of research for years. Some of this research has focused on various applications ranging from using cotton gin by-products (CGB) as fire logs (Karpiscak et al., 1982), an energy source (LePori et al., 1982; White et al. 1996)), livestock feed (Conner and Richardson, 1987; Poore and Rogers, 1995), raw materials in asphalt roofing products (Kolarik and Smith, 1978), and compost (Shumack et al., 1991; Ayers, 1997). The amount of research that has been performed on this subject is more extensive than indicated in the previous examples. For a more thorough overview of previous research efforts, refer to Thomasson, 1990.

One of the major obstacles encountered when trying to utilize CGB in the past has been the maintenance and operational cost associated with processing the product (Skains, 2000; Throckmorton, 2000; Arnold, 2000). CGB, by their very nature contain varying amounts of sand and dirt depending on the crops geographical location, method of harvest, and other factors. Due to the quantity of soil particles (primarily sand) traditionally associated with CGB, excess wear of the processing equipment occurred, thus prompting the need to "clean" the byproduct prior to use. 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). However, even with the best cleaning systems, not all the sand was removed. 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. In addition, Holt et al., 2000, showed that collecting CGB generated from various equipment, instead of combining all the by-products streams into one, in the ginning process can significantly improve certain characteristics such as ash content and heating value.

A patent application has been submitted for a procedure developed at the USDA Lubbock, TX cotton ginning laboratory to enhance the value of CGB. The system is known as the COBY (COtton BYproducts) process and is designed as a value-added operation to produce either a livestock feed, fertilizer, fuel, and/or mulch utilizing the same basic equipment regardless of the final product desired. In the preliminary phases of developing the process, it appeared that the COBY process had an additional benefit of reducing the abrasiveness of the CGB. This hypothesis was a result of noticing the processing equipment pulling significantly less amperage (15 to 20 amps) when processing the CGB that had been treated with the slurry composed primarily of gelatinized starch and water than did the byproducts that were treated with only hot water. Due to our observations during testing, we decided to see if indeed there was a reduction in wear to the processing equipment as a result of the COBY process.

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Most wear resistance standards, such as ASTM G65-94 (ASTM, 1994) and EN 12373-9 (CEN, 1998), focus on using a uniform abrasive material to evaluate an applied coating or metal surface. However, even though the coating concept was the same, the focal point was different. The current standards focus on coating various materials and then evaluating wear utilizing a uniform abrasive. In the case of the COBY process, the focus is on the treatment of the abrasive material, CGB, which are non-uniform. Therefore, this study was designed to focus on applications of various treatments using the COBY process on the non-uniform abrasive CGB material to see how wear of the processing equipment was affected.

Equipment, Materials, and Procedures

COBY Process

The operation involves processing raw CGB which consists primarily of burs, sticks, leaves, lint, and immature seed. Figure 1 shows a schematic of the process. The raw product is conveyed into a live-bottom bulk storage bin. From the bulk storage bin, the CGB are fed, via a variable speed drive system, to a blending conveyor which sits beneath spray nozzles. The spray nozzles apply a slurry comprised primarily of gelatinized starch and water to the CGB. The blending conveyor distributes the applied treatment and carries the product under ingredient feeders which are used to apply various additives that are either helpful in processing or add value to the final product. The blending conveyor then blends and conveys the raw materials to an extruder. The extruder is used to cook, gelatinize, sterilize, and/or create a reaction chamber for the product. In certain instances, additional additives are injected into the processor to either enhance the value of the product or aid in processing. From the processor, the product is conveyed under additional ingredient feeders to either a pellet mill or a belt drier. Finally, the product is either cooled or stored.

CGB Used

The two sources of CGB used in this experiment came from the gins at the Cotton Ginning Research Unit in Stoneville, MS and the Cotton Production and Processing Research Unit in Lubbock, TX. The CGB from Stoneville included material from two inclined cleaners, stick machine, and an extractor feeder and consisted, on a weight basis, of 2.8% lint, 9.8% sticks, 42.4% burs, 5.9% dust less than 100 microns in size, and 39.1% other miscellaneous matter such as leaves and immature seeds. Lubbock CGB were obtained from two combination stick and bur machines and consisted of 0.2% lint, 10.7% sticks, 88.7% burs, 0.3% dust less than 100 microns in size, and 0.2% other miscellaneous matter. The results were obtained by air washing and then fractionating five separate samples of the raw product. The portion of the fractionated samples that contained lint where run through a Shirley Analyzer to obtain the quantity of lint. Figure 2 shows the particle size distribution, obtained from a separate sieve analysis, of the CGB used in this study.

Setup and Procedure

Figure 3 shows a schematic of the equipment used to evaluate abrasiveness of the treated CGB. The existing equipment used in the COBY process was deemed the best means of evaluation since it would be almost identical to process operation. Equipment used consisted of a cook kettle, starch pump, bulk feed bin, mixing/conveying augers, feeders (volumetric and side feeder to the extruder), and extruder. Since we wanted to perform multiple replications over a relatively short period of time, several items needed to be modified prior to testing. Items modified from normal operation included removal of the nose cone, located at the discharge end, and installation of an aluminum steam lock (wear disk), made of aluminum alloy 6061-T6, in place of the cast iron one commonly used (figure4). The aluminum steam lock was our wear disk. The nose cone was removed to allow for observation during testing and to help expedite the turn-around between runs. The turn-around was reduced since it was not necessary to breakdown the extruder after each and every run, rather just remove the nose bullet (part of the extruder holding the wear disk in place) and the used wear disk, install a new one and then proceed with the next run.

For our tests, we evaluated CGB from two sources using three separate treatments: 1) CGB with 4% hot water added , 2) CGB with a 4% gelatinized starch mixture added, and 3) CGB with a 4% gelatinized starch and 4% dry starch mixture. For each treatment, the percent added was by weight of CGB processed. For example, if CGB were being fed from the bulk feed bin at a rate of one ton per hour, then 80 pounds of water would be added for the 4% hot water treatment. The dry starch was added in the blending augers via the ingredient feeder (figure 3). Prior to each treatment, we preconditioned the extruder for twenty minutes. Preconditioning was necessary in order to get the extruder up to testing temperature, for a given treatment, and also to eliminate any border effects that could occur from the treatment previously performed. For instance, if a starch treatment was followed by the water only treatment, it was important to make sure that all starch products were cleared out of the auger troughs and extruder prior to running the runs for the water treatment. For all starch treatments, hot water and gelatinized starch mixtures were mixed at a ratio of 1 lb of starch for every gallon of water. All treatments were applied at 185 to 190°F.

Experimental Design and Analysis

This experiment was analyzed as a randomized block design experiment consisting of CGB from two locations applying three treatments with each treatment replicated four times. Standard analysis of variance techniques were used to analyze the data to determine statistically significant differences among the three treatments by the Ryan-Einot-Gaberiel-Welsch Multiple Range Test at the 95% confidence interval.

Results

The results are shown in Tables 1, 2, 3, 4, and 5. The mean values shown in Tables 1, 2, and 3 are in terms of pounds of aluminum removed per ton of CGB processed. Table 1 indicates a significant difference in wear as a result of applying the gelatinized starch. Compared to the water only treatment, both starch treatments resulted in a reduction of wear. The 4% gelatininzed starch and the 4% gelatinized/dry mix treatments resulted in a 27.5% and 28.6% reduction in wear, respectively.

Tables 2 and 3 show the treatment effects on the basis of the CGB point of origin. Table 2 illustrates that a significant difference ($P < 0.05$) in wear was not noticed for the CGB from Stoneville even though the starch treatments demonstrated slightly lower wear numbers than did the water treatment. However, Table 3 shows that a significantly less wear was noticed on the starch treatments than the water treatment for the Lubbock CGB. The primary difference between the two is the uniformity of treatment application. The CGB from Stoneville had greater amounts of lint that would "ball up" and cause the byproducts to feed erratically form the bulk feed bin. Conversely, the byproducts from Lubbock had very little lint and were fairly uniform in size, as seen in figure 2, and fed out of the bulk feed bin smoothly. Whereas the Stoneville product would come out of the bulk feed bin in clumps thus preventing the treatment, being applied from the spray nozzles, from penetrating into the "ball" of CGB. Even with the mixing auger and the time of travel to the extruder (35 to 45 seconds), some of the Stoneville byproducts still were not evenly coated with the treatment before entering the extruder. This caused "dry" spots, not seen in the CGB from Lubbock, that would have resulted in increased friction and wear which can be seen in Tables 4 and 5 in terms of an increase in extruder temperature.

Tables 4 and 5 show the average extruder barrel temperatures obtained during testing for the Stoneville and Lubbock sources of CGB evaluated, respectively. In table 4, significant differences in extruder barrel temperatures, based on treatment, were noted. The highest temperature was obtained with the treatment, 4% starch, that had the lowest average wear (table 2) followed by the 4% water and the 4% mixed starch treatments. Table 5 indicated significant differences in barrel temperatures with 4% water having the highest processing temperature followed by 4% starch and 4% mixed starch, respectively. Also, the Lubbock CGB had smaller deviations from the mean barrel temperature than did the Stoneville CGB. It is believed that the temperature variations for the Stoneville product was due in large part to the way the material fed out of the bulk feed bin.

It should be noted that the average barrel temperature obtained in the standard COBY operation is between 220 and 240 °F. The lower temperatures obtained in these tests, compared to operational temperatures, were due primarily to the fact that the nose cone and additional steam-locks used during normal operation were not used for the test runs. The nose cone and additional steam-locks result in greater restrictions that increase both temperature and pressure. Even though the barrel temperatures were below the standard operating temperatures, the barrel temperatures recorded during testing were relatively constant throughout all replications. Thus, for the configuration used, the barrel temperatures would be expected to be similar to those listed in tables 4 and 5 if the same tests were repeated.

Summary

The abrasiveness of CGB has been one of the major cost factors associated with value-added processes. The cost associated with cleaning and the wear of the equipment can often times amount to half the total cost of processing alone. A value-added process, known as the COBY process, developed at the Lubbock, TX USDA-ARS cotton ginning laboratory showed signs of reducing the abrasiveness of CGB. To determine if and to what degree the abrasiveness was reduced, tests were performed on two sources of CGB one from Stoneville, MS and the other from Lubbock, TX using three different treatments. The treatments included adding the following, on a weight basis, to the CGB: 1) 4% hot water, 2) a 4% gelatinized starch and 4% dry starch mixture, and 3) 4% gelatinized starch. In addition to wear reduction, the effect of the treatments on processing temperature was also documented.

Overall, the addition of a gelatinized starch, in the COBY process, results in a significant ($P<0.05$) reduction in wear of the processing equipment. Significant reductions in wear were observed for the 4% gelatinized starch mixture and the 4% gelatinized starch and 4% dry starch mixture treatments. Compared to the hot water treatment, the 4% gelatinized starch had 27.5% less wear and the 4% gelatinized/dry mix had 28.6% less wear. However, the CGB from Stoneville demonstrated the need for uniform application of the treatment since differences in wear for these by products were not as prevalent due to application irregularities. Whereas the byproducts from Lubbock, which received uniform application of the treatments, demonstrated a significant reduction in wear as a result of being treated with starch. Significant differences in extruder barrel processing temperatures were noted for both CGB from Lubbock and Stoneville. For any given treatment, the temperatures obtained when processing the CGB from Stoneville were 8 to 22% higher than those of the same treatment for Lubbock.

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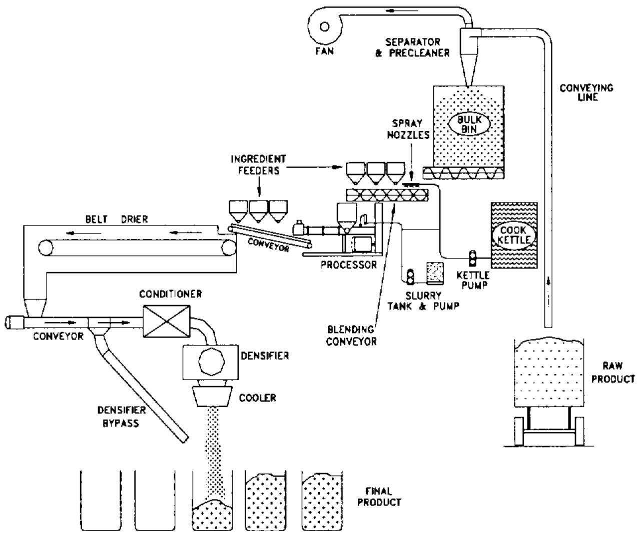

Figure 1. Schematic flow diagram of the COBY process.

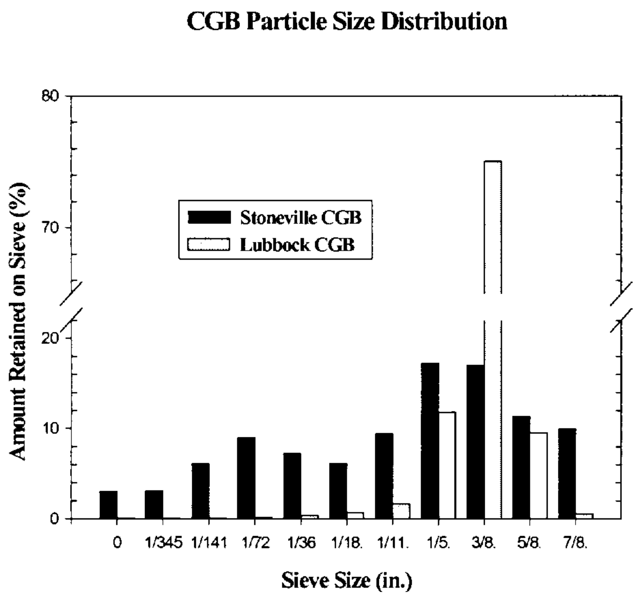

Figure 2. Sieve analysis for stoneville and lubbock cotton gin byproducts.

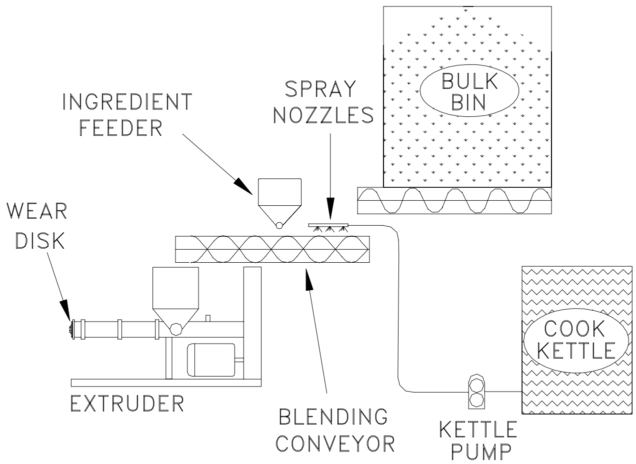

Figure 3. Schematic of COBY equipment used in performing test runs.

Figure 4. Aluminum wear disk used for test (left) versus conventional cast iron steam lock used in the extruder (right).

Table 1. Total average wear in pounds of aluminum removed per ton of cotton gin byproducts (CGB) processed, from both Stoneville and Lubbock sources.

Mean Weight Loss (lbs/ton)	CGB Treatments Evaluated*: 4% Hot Water	4% Gelatinized & 4% Dry Starch	4% Gelatinized Starch
Wear Plate	0.258a	0.184b	0.187b

* Means followed by the same letter are not significantly different at the 0.05 level of significance.

Table 2. Average amount of wear in pounds of aluminum removed per ton of Stoneville cotton gin byproducts (CGB) processed.

Mean Weight Loss (lbs/ton)	CGB Treatments Evaluated*: 4% Hot Water		4% Gelatinized & 4% Dry Starch		4% Gelatinized Starch	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Wear Plate	0.253a	0.034	0.246a	0.041	0.214a	0.013

* Means followed by the same letter are not significantly different at the 0.05 level of significance.

Table 3. Average amount of wear in pounds of aluminum removed per ton of Lubbock cotton gin byproducts (CGB) processed.

Mean Weight Loss (lbs/ton)	CGB Treatments Evaluated*: 4% Hot Water		4% Gelatinized & 4% Dry Starch		4% Gelatinized Starch	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Wear Plate	0.263a	0.027	0.122b	0.025	0.159b	0.071

* Means followed by the same letter are not significantly different at the 0.05 level of significance.

Table 4. Average extruder barrel temperature obtained during testing for each treatment of Stoneville CGB evaluated.

Average Extruder Temp. (deg. F)	CGB Treatments Evaluated*: 4% Hot Water		4% Gelatinized & 4% Dry Starch		4% Gelatinized Starch	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Extruder Barrel	108.5b	3.0	100.8c	3.8	118.0a	4.1

* Means followed by the same letter are not significantly different at the 0.05 level of significance.

Table 5. Average extruder barrel temperature obtained during testing for each treatment of Lubbock CGB evaluated.

Average Extruder Temp. (deg. F)	CGB Treatments Evaluated*: 4% Hot Water		4% Gelatinized & 4% Dry Starch		4% Gelatinized Starch	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Extruder Barrel	99.7a	2.7	86.7c	0.9	92.5b	1.7

* Means followed by the same letter are not significantly different at the 0.05 level of significance.