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ENGINEERING AND GINNING

Development and Evaluation of a Novel Bench-Top Mechanical Cotton Seed Delinter for Cotton Breeders

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ABSTRACT

Acid delinting of cotton seed presents a personal safety and potential environmental hazard for cotton breeders. A means of delinting that does not use acid, but is effective at removing linters without adversely impacting germination is needed. A prototype mechanical cotton seed delinter was developed and built at the United States Department of Agriculture – Agricultural Research Service (USDA-ARS), Cotton Production and Processing Research Unit in Lubbock, Texas in order to optimize the mechanical process of delinting cotton seed. Testing evaluated seven drum linings, one or two roller brushes used for "scrubbing" lint from the cotton seed, and two processing times, five and ten min. The primary performance metrics evaluated were lint loss (i.e. residual lint remaining on the seed after processing) and germination. Other metrics such as visible mechanical damage of the seed and visual observations of durability and ease of clean out were also noted. Results revealed an alternating brush pattern of half nylon and half steel wire bristle brushes (42N42W) to be the best drum material using either one or two roller brushes at ten min of processing time. Lint loss values of the 42N42W material with one or two roller brushes at ten min were 0.95% and 0.88%, respectively. Germination rates for 42N42W at five and ten min were 89.3% and 88.4%, respectively. The 42N42W material appeared to be the most durable and was one of the easiest materials evaluated to clean out between samples. Based on findings in this study, a commercial unit for breeders was built by BC Supply in Lubbock, Texas. The findings of this study will be used in the development of a larger-scale model to process bulk quantities of seed during commercial production.

In cotton gins, the process of ginning involves separating the fiber from the seed. The fiber and seed are both revenue generators for producers and ginners alike; the fiber for textiles and the cotton seed for further processing (oil, linters, hulls, and meal), whole seed feeding and planting seed. When cotton seed is processed by an oil mill, the four products previously mentioned are generated. However, when planting seed is the desired product, fuzzy cotton seed needs to be delinted (i.e. linters need to be removed from seed, Fig.1) in order to facilitate grading, cleaning, allow for more uniform application of seed treatment, and for the seed to flow through the planter and be properly handled by the seed metering mechanism. Even though fuzzy cotton seed can be planted, it is unsuitable for mechanized agriculture where hand planting is not performed.

Figure 1. Picture of fuzzy cotton seed (left) and acid delinted cotton seed (right).

There are two methods utilized for delinting cotton seed, mechanical and acid. Mechanically saw-delinted seed retains 1-2% residual linters whereas acid-delinted seed removes all linters and is primarily used for production of planting seed (Cotton Inc., 2014). The need for a process that removes linters from cotton seed has been of interest to inventors and the cotton industry for over a century (Dudley, 1886; Marshall, 1890; Reid, 1912). Most of the early

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inventions focused on mechanical processes such as re-ginning the seed (Payne, 1870; Overmyer, 1907; Holt, 1917) or using abrasives, scraping, or scouring (Marshall, 1890; Reid 1912; Sheppard, 1939). Even though a majority of the early cotton seed delinting patents and inventions focused on mechanical methods, other processes were patented such as a flammable liquid and flame (McLemore, 1948), a flame treatment apparatus (Downing, 1980) or acid (Dudley, 1886; Polhamus, 1922; Holloman and Stukenborg, 1937).

The main arguments for using acid were that the mechanical processes damaged the seed (i.e. crushing reducing, or killing germination due to mechanical heat) and/or did not sufficiently remove the linters. Also, the use of acid for delinting planting seed has been shown to reduce microbial contamination and control various diseases (Delouche, 1986). Consequently, acid delinting became, and still is, the primary means of producing planting quality seed for modern agriculture. The use of acid for producing planting seed can include wet acid or gas (American Delinting, 2014). Sulfuric is the most common wet acid found in the literature (Smith, 1980; Downing, 1981) with hydrochloric being the most common acid gas (Downing, 1977; Wadlington, 1997; Dismuke et al, 1997). The use of an acid, for delinting cotton seed, may be desirable in removing linters for planting seed but is not a desirable process from an environmental protection, repair and maintenance of equipment perspective, or if the seed were to be used as a protein source for humans.

Historically, cotton seed has not been a viable source of protein for non-ruminants and humans due to gossypol (Merck, 2012; Gadelha et al., 2014). However, a Texas A&M University researcher, was able to silence the gene responsible for gossypol production in the cotton seed (Swaminathan, 2006) allowing for its potential use as human protein source (Hearn, 2006; Associated Press, 2009). Consequently, work began in earnest to find a more food-friendly way of extracting cotton seed meats from the hull (Nunneley et al., 2013a; 2013b). In some of the research conducted, the hull of naked (lint-free) or near-naked seed was removed more effectively than fuzzy seed. The use of acid in any processing step involving low-gossypol or gossypol-free seed as a protein source for humans could result in significant obstacles to Food and Drug Administration (FDA) approval of the seed for human consumption. Consequently, a mechanical means of delinting cotton seed that could potentially be a viable human protein source is preferred. Simultaneously, cotton seed companies and commercial and private sector cotton breeders have expressed an interest in a non-acid delinting process due to regulatory (environmental and safety) and maintenance issues (corrosiveness) with running acid delinting operations. Hence, the need to produce a non-acid delinting process has come full circle.

The idea of abrasive delinting has never ceased to be an area of development since the early patents from the late 1800's (McMath, 1955; Williams, 1974; Harrington et al., 1977; Davis, 1985; Kincer et al., 1990; Jones, 1993; Thrash, 1995; Darrell, 2006). The problem is that even though some of these technologies might be suitable for delinting cotton seed for use in engineered edible cotton seed dehulling operations or for planting seed, they have not proved suitable for both. Most of the patented mechanical processes have limitations such as throughput, effectiveness, and/or producing too much heat and therefore reducing germination. Consequently, there was a need to develop a mechanical process that could produce delinted (naked) seed for both planting and engineered edible cotton seed processes that overcame the issues noted in previous designs. A mechanical cotton seed delinter envisioned by Wedegaertner (2012) appeared to be a solution to the deficiencies that plagued other mechanical delinting processes but the design had a low processing rate and needed improvements to increase lint removal efficiency. The modifications to the Wedegaertner design (Wedegaertner and Holt, 2014; Wedegaertner and Holt, 2015) improved performance and throughput but optimization was needed to encourage commercial manufacturing and industry adoption. The objective of this study was to determine the most effective design and operational factors of a bench-top scale mechanical delinter for use by commercial and public cotton breeders.

METHODS AND PROCEDURES

Equipment. A prototype mechanical cotton seed delinter (MD) was built to conduct the testing (fig.2). Fig. 3 shows the entire system, the MD along with the air system used to collect the lint removed from the seed during processing. Fig. 4 shows the specific components of the MD: 1) drum, 2) roller brushes, 3) motor, and 4) drive wheels. The drum rotated at 283 rpm and was lined with different abrasive materials for a total of seven drum setups (figs. 5-11). Of the seven drum setups, one was a bare drum with no abrasive (None). The other six setups consisted of commercially available abrasive materials: 1) 3M Purple ScotchBrite^{TM} (PurpleSB), 2) 3M Clean & Strip^{TM} (ClStrip), 3) 3M Brushlon^{TM}, 80 grit (Brushlon 80), 4) Nylon brush (0.10 cm diameter crimped bristle, 3.81cm bristle height, manufactured by Carolina Brush Company, Gastonia, NC) (CarolinaB), 5) Nylon brush and Wire brush combination (72 nylon from Carolina Brush Company, Gastonia, NC and 12 steel wire from Power Brushes, Inc., Toledo, OH; wire was crimped, 0.03 cm diameter with a 3.81 cm bristle height) (CBw12wb), and 6) Nylon and Wire brush combination, 50/50 (42 nylon from Carolina Brush and 42 steel wire from Power Brushes Inc.) (42N42W). The drum, without abrasive material, was 30.48 cm inside-diameter and 20.3 cm wide.

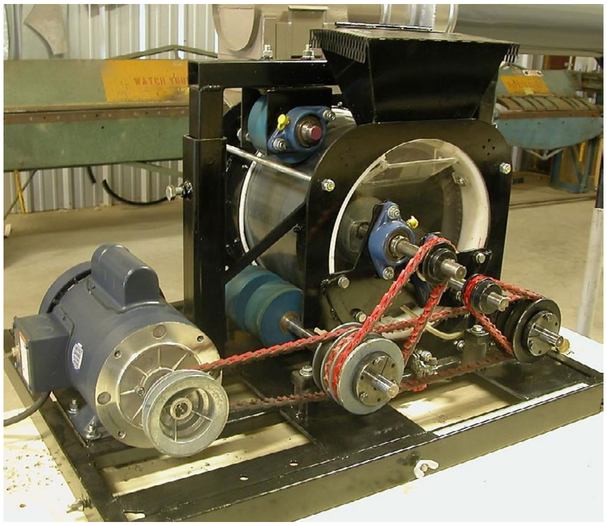

Figure 2. Prototype mechanical cotton seed delinter used to collect the data presented in this study.

Figure 3. Picture of the entire mechanical delinting system used for this study showing air system to collect lint removed from the cotton seed during processing in the mechanical delinter.

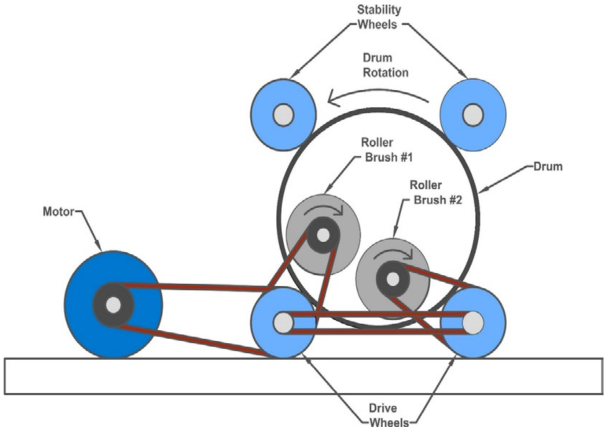

Figure 4. Schematic of the bench-top mechanical delinter showing main components of the unit.

Figure 5. Close-up and side view of the None drum lining used in this study. The drum lining consisted only of roughing up the interior surface of the drum with a hand grinder.

Figure 6. Close-up and side view of the 3M Purple ScotchBrite^{TM} drum lining used in this study. The drum lining was affixed with adhesive into the interior of the drum.

The roller brushes (RB#1 and RB#2) were made from ten wire wheel brushes that were bored out to fit on a 2.54 cm shaft with a 0.32 cm keyway. The wire wheel brushes were stacked onto the shaft and locked in place by a flat steel plate welded to the shaft. Wire wheel brushes had brass-coated steel crimped wire, 0.03 cm in diameter with a wheel diameter of

10.16 cm and a bristle length of 1.75 cm. The roller brushes were gapped at 0.71cm (RB #1) and 0.20 cm (RB #2) from the drum material for all setups. The gap between the brushes were set at 0.84 cm. Roller brushes rotated at speeds of 1400 rpm (RB #1) and 2000 rpm (RB #2).

Figure 7. Close-up and side view of the 3M Clean & Strip™ drum lining used in this study. The drum lining was affixed with adhesive into the interior of the drum.

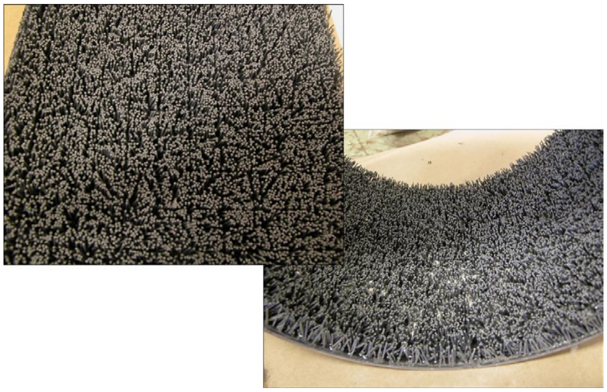

Figure 8. Close-up and side view of the 3M Brushlon, 80 grit drum lining used in this study. The drum lining was affixed with adhesive into the interior of the drum.

Figure 9. Close-up and side view of the Carolina Brush, 0.1cm crimped bristle diameter 3.81 cm in length, drum lining used in this study. Each brush was affixed with tack-welds on both ends of the drum, for a total of 84 brushes.

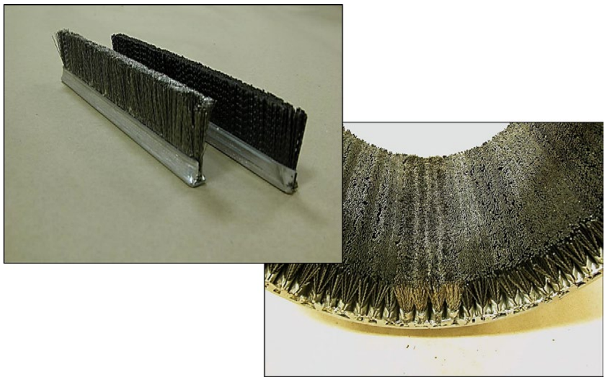

Figure 10. Close-up and side view of the Carolina Brush, from Fig. 9, with 12 wire brushes, 0.03 cm diameter 3.81 cm in length, drum lining used in this study. Each brush was affixed with tack-welds on both ends of the drum, for a total of 84 brushes.

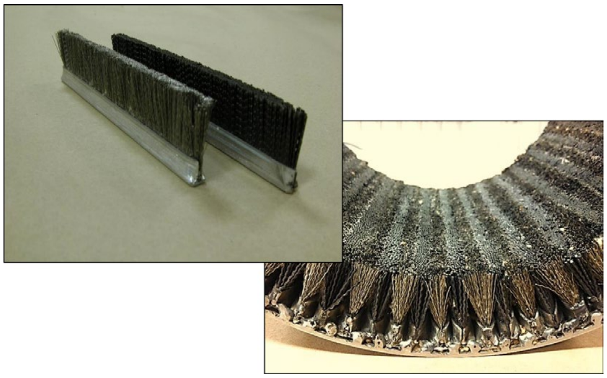

Figure 11. Close-up and side view of the nylon and wire brush combination (42N42W) used in this study. Each brush was affixed with tack-welds on both ends of the drum for a total of 84 brushes, half nylon (Fig. 9) and half wire (Fig. 10).

The motor powering the MD was a 0.75 kW Leeson, model number C6C17FK5L (Leeson Electric Company, Grafton, WI). From the motor a belt drive system was used to power the drive wheels, abrasion-resistant urethane drive rollers with steel hubs, part number 2475K74 (McMaster-Carr, Elmhurst, IL). Pulleys on the drive wheel shafts were used to power the roller brushes as shown in Fig. 4. The drive wheels and stability wheels were identical with the exception that the stability wheels were not powered.

The air system used to remove the lint fly (i.e. linters removed from the seed) from the drum during operation (fig. 12), had a velocity of 246 m/min in a 15.2 cm diameter pipe. A Dayton Blower centrifugal fan model number 4C129A (Dayton Electric Manufacturing Company, Niles, IL) was used to pull air through a 30.5 cm diameter 1D-3D cyclone that conveyed the lint fly to a collection container at the bottom of the cyclone cone. The Dayton fan was powered by a 1.1 kW Dayton motor, model number 6K365D (Dayton Electric Manufacturing Company, Niles, IL).

Figure 12. Close-up view of the air system used to pull and collect the lint from the prototype mechanical cotton seed delinter during cotton seed processing. The air system consisted of cyclone, fan, collection system, and ducting.

Testing. The MD configurations tested included all combinations of: 1) seven drum setups, six abrasives and one bare drum (previously discussed); 2) number of RB (one brush or two: when one RB was used it was installed in the #2 brush position); and 3) two time intervals of operation, five and ten min. Three replications of 340 g samples of fuzzy cotton seed (FCS) were used to test each combination. The FCS used in this study was a composite of several cultivars that originated from the United States Department of Agriculture-Agricultural Research Service (USDA-ARS), Lubbock gin laboratory's seed storage facility (seed house) and not from a specific test. The procedure for testing started with randomly selecting a drum material (setup) to evaluate, and installing the drum with chosen setup in the MD. The number of brushes (one or two) to test was randomly selected along with the time interval for testing. Due to the difficulty of replacing the drum setups and roller brushes, all three replications of each drum setup, roller brush configuration (one or two brushes), and time interval combination was tested, before changing to the next configuration. The specific procedure for each test was: 1) weigh out fuzzy seed samples and collect baseline FCS samples for seed analysis of each test lot, 2) energize the MD and air system motors, 3) feed FCS sample into MD, 4) start timer, 5) run for predetermined time interval and turn off power to MD, the air system power was still active to help remove residual lint during seed extraction from MD, 6) remove delinted seed while "bumping" the MD to make sure seed was discharged out the opposite side of the feed input, 7) blow out residual lint, and seed (if needed), while the air system was still operational (clean out), 8) turn off air system and collect seed and lint from the cyclone catch container , 9) weigh seed and lint portions separately, and 10) repeat process for the next run.

Analysis. The FCS and moisture samples collected from each lot (item #1 for specific procedures above) were analyzed separately. The moisture samples were analyzed in-house as per Shepard (1972). The FCS samples were sent to Delta and Pine Land Company's seed processing plant that has seed quality analytic capability in Aiken, Floyd County, Texas for lint loss (LL) and germination (Germ) analyses. The FCS samples were used to determine the average baseline of LL and Germ for the cotton seed used in the study. All seed and lint samples from each run were analyzed for LL (AOCS, 1997), visible mechanical damage (VMD) (McCarty and Baskin, 1978), and Germ (Hake et.al., 1990). Lint loss is a measure of residual lint remaining on the seed after processing; the lower the LL value the better the process was at cleaning the seed. Visible mechanical damage is a visual means of evaluating seed quality. The VMD classification system ranks damage (the number of cut or cracked seed coats) into low, medium, and high categories where a classification of high indicates major damage that adversely impacts germination. The Total VMD number is the summation of the low, medium, and high counts obtained by the method. The lint samples were collected and sent to the USDA-ARS, Southern Regional Research Center, New Orleans, Louisiana for Advanced Fibre Information System (AFIS) fiber analysis to determine mean length and short fiber content (both by weight and number).

Statistical analyses were performed with drum setup, number of brushes, and time of operation as fixed factors. The analysis was performed using Proc Glimmix with a Beta response distribution (release 9.3, SAS Institute Inc., Cary, NC). Analysis of Variance was performed on each response variable and means separation was conducted with Tukey's HSD test. A 0.05 level of significance was used for all tests (a= 0.05).

RESULTS

The average moisture content of FCS used in this study was 7.58% (wet basis) with a standard deviation of 0.36%. Average LL and VMD for all treatment combinations evaluated are shown in Figs. 13 and 14. The control lint loss number of 11.5%, in Fig. 13, was the baseline LL for the fuzzy seed before any processing. Likewise, the Control High VMD in Fig. 14 was the VMD of the fuzzy seed after acid delinting. The drum setup with no abrasive (None) was the least effective at removing lint from the seed for all MD configurations evaluated (fig. 13). The second least effective drum setup at lint removal was Brushlon 80. Even though the averages for Brushlon 80 were similar to Carolina B, the Brushlon 80 lining was cumbersome to work with because many of the seeds would become lodged in the bristles. Cleaning out the inside of the Brushlon 80 drum created a significant amount of work in between each run, thereby resulting in removal of that setup from consideration as a viable drum lining. A visual reference of the difference in lint removal efficiency between Brushlon80 and 42N42W is shown in Fig. 15.

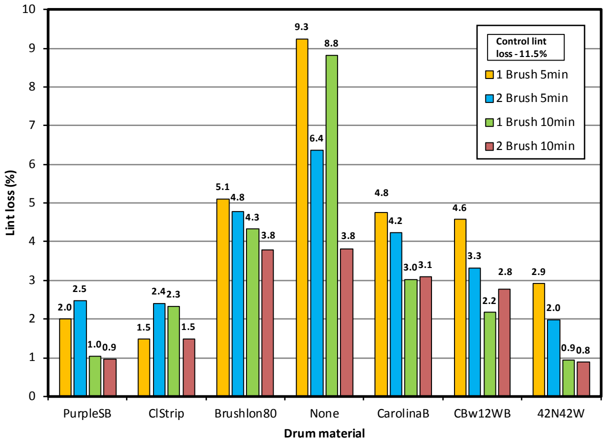

Figure 13. Mean percent lint loss (LL) from three replications for each mechanical delinter configuration (i.e. drum material, number of brushes, and processing time) tested in this study.

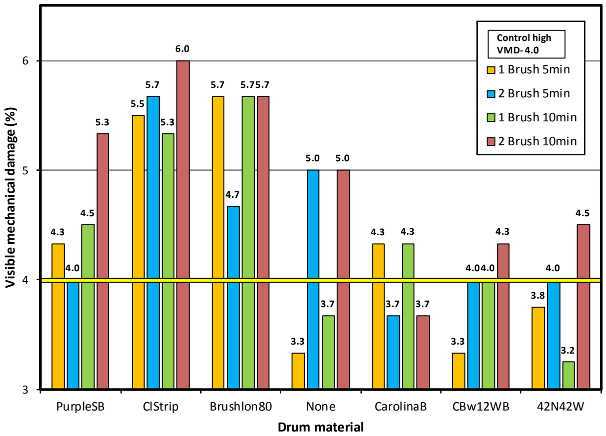

Figure 14. Mean high visible mechanical damage (VMD), from three replications, for each mechanical delinter configuration (i.e. drum material, number of brushes, and processing time) tested in this study. High VMD is the worst visual classification ranking where damage to the cotton seed is deemed to negatively impact germination.

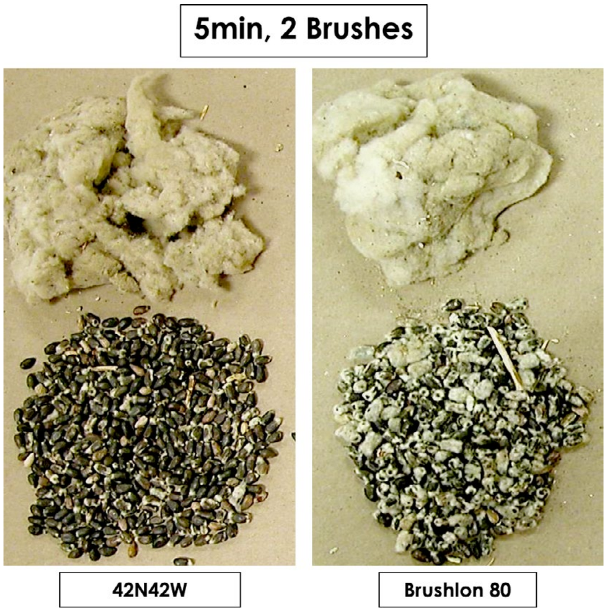

Figure 15. Picture showing the cotton seed and lint from two of the mechanical delinter configurations tested, 42N42W – five min – two roller brushes (left) and Brushlon80 – five min – two roller brushes (right).

From Fig.14 the High VMD values showed the Brushlon 80 and ClStrip drum setups to have a higher VMD value than the control for all MD configurations. The reason for evaluating drum setups based on VMD was to see how much additional damage, if any, resulted from the mechanical process. Even though most of the MD configurations did not result in comparitively high damage in regards to the control, the metric was used in conjunction with LL to determine which setups might be removed from additional analysis and consideration for commercial application. Consequently, both the Brushlon 80 and None drum setups were discarded from further analysis. Even though ClStrip had higher average VMD numbers, the LL values were noticably lower than the None or Brushlon 80 setups for all MD configurations evaluated; thus keeping ClStrip as a viable drum lining for consideration.

The type III test for fixed effects at the 0.05 level of significance, for LL, revealed drum setup (<.0001), processing time (<.001), and the three-way interaction of drum setup*number of roller brushes*processing time (0.0277) to be significant. The least squares means for LL by drum setup, number of RB, and processing time are shown in Table 1. The drum materials with some of the lowest LL were 42N42W and PurpleSB. The lowest mean LL was observed in 42N42W – 2 RB – 1ten min followed by 42N42W – 1 RB – ten min. Significant differences were noted in LL due to an increase in the number of RB and processing time for at least one configuration in every drum material except ClStrip. Even though ClStrip had a lower average for the 1 RB - five min configuration than for the 1 RB - ten min or the 2 RB - five min configurations, no significant differences existed between any of the ClStrip configurations.

Type III testing for fixed effects associated with Germ showed the significant effects at the 0.05 level of significance as drum setup (0.0227), processing time (0.0241), and the two-way interaction of drum setup*processing time (0.0150). The least squares means for Germ by drum setup and processing time are shown in Table 2. The highest mean Germ was seen in the PurpleSB at five min (94.3%) followed by CarolinaB – five min (91.5%), 42N42W – five min (89.3%), ClStrip – ten min (88.5%), and 42N42W – ten min (88.4%). Within a given drum setup, only CBw12wb and PurpleSB had significant differences in Germ associated with processing time. CBw12wb had significantly higher Germ at five min (85.5%) than ten min (72.3%) as did PurpleSB, 94.3% - five min versus 80.5% - ten min.

For germination, there were two baseline values obtained, fuzzy seed and acid-delinted seed. Fuzzy seed baseline was 78% and acid delinted baseline was 87%. Even though both baseline Germs were obtained using the same protocol (Hake et.al., 1990), the difference was attributed to the fact that the acid baseline removed the immature seeds prior to the Germ test while the fuzzy baseline did not. Another way of viewing the two baselines is one was “as is” (fuzzy) and the other was delinted (acid) and sorted to remove undesirables, the current practice for seed companies.

Table 1. Lint loss as affected by drum setup, number of rollers, and processing time

Least Squares Means for Lint Loss				
Drum Setup^z	**Number of Roller Brushes**	**Processing Time (min)**	**Lint Loss^y (%)**	**Lint Loss SEM^x**
42N42W	**1**	**5**	**2.91 efd**	**0.34**
42N42W	**1**	**10**	**0.95 i**	**0.19**
42N42W	**2**	**5**	**1.99 gh**	**0.28**
42N42W	**2**	**10**	**0.88 i**	**0.19**
CBw12wb	**1**	**5**	**4.58 ab**	**0.50**
CBw12wb	**1**	**10**	**2.17 efgh**	**0.34**
CBw12wb	**2**	**5**	**3.33 bcd**	**0.43**
CBw12wb	**2**	**10**	**2.77 defg**	**0.39**
CarolinaB	**1**	**5**	**4.76 a**	**0.51**
CarolinaB	**1**	**10**	**3.03 cdef**	**0.41**
CarolinaB	**2**	**5**	**4.23 abc**	**0.48**
CarolinaB	**2**	**10**	**3.10 cde**	**0.41**
ClStrip	**1**	**5**	**1.48 hi**	**0.35**
ClStrip	**1**	**10**	**2.33 defgh**	**0.36**
ClStrip	**2**	**5**	**2.41 defgh**	**0.36**
ClStrip	**2**	**10**	**1.49 hi**	**0.28**
PurpleSB	**1**	**5**	**2.00 fgh**	**0.33**
PurpleSB	**1**	**10**	**1.04 i**	**0.29**
PurpleSB	**2**	**5**	**2.48 i**	**0.37**
PurpleSB	**2**	**10**	**0.96 i**	**0.22**

[z] 42N42W = 42 nylon brushes and 42 wire brushes; CBw12wb = Carolina Brush with 12 wire brushes; CarolinaB = Carolina Brush with nylon brushes; ClStrip = Clean&Strip; PurpleSB = Purple ScotchBrite.

[y] Lint Loss means with the same letter are not significantly different at the 95% confidence interval

[x] SEM = Standard Error Mean

Table 2. Seed germination as affected by drum setup and processing time

Least Squares Means for Germination			
Drum Setup^z	**Processing Time (min)**	**Germination^y (%)**	**Germination SEM^x**
42N42W	**5**	**89.3 abc**	**2.9**
42N42W	**10**	**88.4 abc**	**3.0**
CBw12wb	**5**	**85.5 bc**	**3.3**
CBw12wb	**10**	**72.3 d**	**4.7**
CarolinaB	**5**	**91.5 ab**	**2.5**
CarolinaB	**10**	**87.0 bc**	**3.2**
ClStrip	**5**	**80.0 cd**	**4.7**
ClStrip	**10**	**88.5 abc**	**3.0**
PurpleSB	**5**	**94.3 a**	**1.8**
PurpleSB	**10**	**80.5 cd**	**4.3**

[z] 42N42W = 42 nylon brushes and 42 wire brushes; CBw12wb = Carolina Brush with 12 wire brushes; CarolinaB = Carolina Brush with nylon brushes; ClStrip = Clean&Strip; PurpleSB = Purple ScotchBrite.

[y] Germination means with the same letter are not significantly different at the 95% confidence interval

[x] SEM = Standard Error Mean

Based on Table 2, the mean Germ exceeded the fuzzy seed baseline (78%) for all MD configurations with the exception of CBw12wb – ten min (72.3%). The CBw12wb – ten min configuration appeared to have mechanical dynamics that adversely impacted germination of the seed or else allowed immature/damaged seeds to pass through the process. In comparison to the acid delinted baseline (87%), the MD configurations with lower means included: CBw12wb – five min (85.5%), CBw12wb – ten min (72.3%), ClStrip – five min (80%), and PurpleSB -ten min (80.5%). One working hypothesis on the improvement in germinaton by some of the MD configurations is the elimination of damaged seed that would otherwise not be eliminated prior to acid delinting in a breeding program's normal seed processing.

The MD configurations that had the best combination of LL and Germ involved 42N42W and PurpleSB. The other configurations such as ClStrip and CarolinaB had acceptable Germ with good to moderate LL. The worst performer was CBw12wb, which had some of the highest LL and the lowest Germ. The Germ for CBw12wb – ten min (72.3%) was significantly lower than every other two-way drum setup*processing time configuration except two, ClStrip – five min (80.0%) and Purple SC – ten min (80.5%). Overall, the 42N42W had the best combined results of all configurations.

In addition to the metrics previously discussed, an observational metric on how easy the drum material was to clean out and the apparent durability of the material was also noted during testing. Durability was an observational evaluation performed on each drum lining after testing was completed. None and Brushlon80 were eliminated as a result of poor performance and difficulty in clean out, respectively. PurpleSB and ClStrip had similar difficulties in that PurpleSB, while having desirable performance under certain RB and time configurations, was not durable due to significant visual wear over the testing period. Similarly, ClStrip appeared to be durable but was difficult to clean out and would trap seed similar to Brushlon80. Consequently, the opinion of the authors was that drum material longevity would be best from brushes or brush-type materials since they were some of the easiest drum materials to clean out and could wear down and the RB be adjusted to maintain tolerance without frequently having to replace the material. This will need to be verified by longevity testing and is mentioned here as an observation noticed during this study.

The mass balance of FCS input (340g) and seed and lint output for each drum setup and processing time are shown in Fig. 16. From Fig. 16, which includes None and Brushlon 80, the None drum lining had the lowest overall reduction in weight with less than 2% for both processing times. However, the amount of cleaning performed by None was inferior to other treatments as previously discussed. The two configurations with the highest amount of total weight loss were the ClStrip (87.7) and 42N42W (91.8) at 10 min. The lint weight percents that are greater than the baseline control (11.5%) are the result of seed (clean or fuzzy) and/or other foreign organic matter such as leaf, sticks, stems, and/or carpel wall being drawn into the lint catch bin through the air system. For example, 42N42W shows a lint weight percent of 12.5% but the baseline was 11.5%. In Fig. 13, the LL was 1% to 2% so the total lint weight, at 100% efficiency, should have been 9.5% to 10.5%. Since the air was not adjusted during the runs, either organic foreign matter or seed was caught up in the air system into the lint catch. In this study, the lint catch was not segregated further to determine how much cotton plant material and seed were contained therein. Overall, the weight difference between the input and the sum of the outputs seemed greater for some of the more aggressive drum materials and longer processing times. Some of the weight difference can be attributed to fragile or immature seeds being removed through the mechanical action of the delinter.

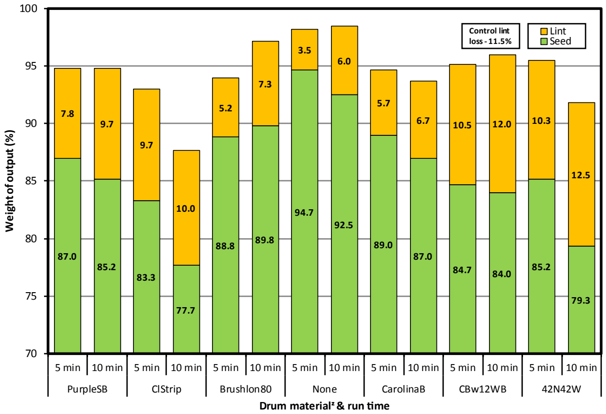

Figure 16. Mean seed and lint output as a percentage of input weight. The sample weight of fuzzy cotton seed for each run was 360 g. Lint weights over the control lint loss of 11.5% contain non-lint portions such as fuzzy seed, clean seed, carpel, and/or sticks.

Advanced Fibre Information System short fibre content (AFIS SFC) and mean length data were also obtained on the lint recovered from each of the configurations. Even though fiber analysis was not a deterministic metric used for evaluation, the SFC and mean length by weight (Lw) and number (Ln) for each drum material evaluated, shown in Table 3, is included for informational purposes as a point of reference. As expected, almost all of the fibers were considered “short”, less than 12.7mm, with an average fiber length, across all treatments, of 5.89mm (Lw) and 4.31mm (Ln).

Table 3. Effect of drum setup on short fiber content and length of recovered lint

Means for Length and Short Fiber Content [z]				
Drum Setup[y]	SFC(w) (%)	SFC(n) (%)	Length(w) (mm)	Length(n) (mm)
PurpleSB	98.2	99.5	5.05	4.16
CarolinaB	97.6	99.4	5.23	4.24
ClStrip	97.0	99.1	5.59	4.52
None	92.6	97.6	6.48	5.03
Brushlon80	97.2	99.2	5.48	4.45
CBw12wb	95.8	98.9	5.48	4.27
42N42W	97.8	99.4	5.13	4.24

[z] **SFC(w) = Short Fiber Content by weight; SFC(n) = Short Fiber Content by number; Length(w) = Length in mm by weight; Length(n) = Length in mm by number. These fiber parameters were obtained by Advanced Fiber Information System (AFIS) analysis.**

[y] **PurpleSB = Purple ScotchBrite; CarolinaB = Carolina Brush with nylon brushes; ClStrip – Clean&Strip; None = no abrasive material in drum, only roughed up surface using hand grinder; Brushlon80 = Brushlon, 80 grit; CBw12wb = Carolina Brush with 12 wire brushes; 42N42W = 42 nylon brushes and 42 wire brushes.**

SUMMARY AND CONCLUSION

A prototype bench-top mechanical cotton seed delinter was built at the USDA-ARS, Cotton Production and Processing Research Unit in Lubbock, Texas for evaluation in developing a mechanical means of delinting cotton seed to replace acid in research and industrial facilities. The evaluation consisted of seven drum linings, one or two roller brushes, and two processing times, five or ten min. Results revealed some of the best configurations included a mixture of wire and nylon brushes using 1one or two rollers for ten min of operation. The mixture of nylon and wire was needed to reduce temperature of the seed during processing. Observationally, the nylon brush bristles appear to dissipate heat and help polish the seed while the wire brush bristles are the prime means of removing the lint in an effective and timely manner. However, if all brushes were wire bristled, the heat generated by the aggressive action of 100% wire brush drum could adversely impact germination. From data not documented in this report, a drum lining comprised of approximately 60% wire brushes appears to be close to the optimum amount of wire brushes without impairing germination. Other abrasive materials such as 3M’s Purple ScotchBrite^{TM} and Clean & Strip^{TM} performed well but were either not durable for this application or were difficult to clean out in between runs. Overall, the 42N42W with two rollers was selected as the best configuration. Operational timing might be dependent on a number of factors, including seed size, fuzz density, and fiber to seed attachment force, known to vary among genotypes (Boykin et al., 2012).

Based on the findings of this research, a meeting was held with a local gin manufacturing company, BC Supply in Lubbock, Texas, to manufacture a processing unit to be commercially available for cotton breeding programs and other research or small-batch applications as a means of replacing acid delinting in their operations. Fig. 17 shows the commercial prototype unit built by BC Supply. The commercial prototype is currently being evaluated by a graduate student in the cotton breeding program at Texas A&M Agrilife Research and Extension Center in Lubbock, Texas. Improvements to the small-batch commercial breeder prototype include:

- Operator stands only on one side and does not have to stand over guarding to feed the unit. Seed discharge is also on the input side so operator does not have to go around behind the unit to evacuate the cleaned seed.
- Easy to access controls of all motors located at one panel to the left of the operator.
- Easily removable end for quicker clean out and access to the interior of the drum and roller brushes.
- Clear plastic collection tube at the bottom of the cyclone so users can see lint being accumulated and when the unit needs to be emptied.
- System is more compact and on casters so the unit can be easily stored when not in use.
- All bearings and drive belts on the backside of the unit easily accessed for maintenance/repair if needed and out of the way of the operator.
- Filter sock to catch fine dust that may exit the air discharge from the fan so it is not dispersed into the room/lab where the unit is operating.

Figure 17. Picture of the commercial prototype mechanical cotton seed delinter built by BC Supply of Lubbock, Texas showing the front of the unit where the operator stands and the cotton seed is fed and recovered from the unit (left). The back (right) of the unit where the motor and drives are located and the fine dust bag (white sock filter at bottom of picture) prevents cyclone overflow from being discharged into the working area.

Additional testing to refine the small-batch commercial unit and determine what, if any, impact varietal differences might have on the performance of the unit are needed. Likewise, the information obtained evaluating the breeder model will be used in the development of a larger scale version to be used for commercial processing.

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DISCLAIMER

Mention of product or trade names does not constitute an endorsement by the USDA-ARS or Cotton Incorporated over other comparable products. Products or trade names are listed for reference only. USDA is an equal opportunity provider and employer.

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