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EFFECTS OF BARK IN COTTON ON TEXTILE PROCESSING COSTS

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Abstract

Textile processing results using cotton with different levels of bark from three different textile processing performance studies were analyzed individually to determine the economic effect of bark in cotton on textile processing. The results indicate that cotton reduced one grade due to bark content added little to processing costs with rotor spinning. However, cotton reduced two grades because of bark added somewhat more to processing cost with rotor spinning, but had a very substantial effect on processing cost with ring spinning. Aggressive cleaning of cotton can reduce processing efficiency losses (costs), but it adds to waste losses.

Introduction

The existence of bark, i.e., pieces of woody material from the stalk and/or branches of the cotton plant, in cotton lint and the costs incurred by its presences affect all segments of the cotton industry. Bark in cotton causes problems for textile mills in various processing stages and/or it may result in impurities or defects in the yarn and fabric, which affects consumers' preferences. Therefore, the bark tends to increase production processing costs and decrease the value of the product. Consequently, bark in cotton represents a lower price (greater discount) to the cotton producer.

Classing of cotton is a procedure which evaluates quality attributes of the cotton fiber; each bale is classed. The market assigns prices to cotton of various quality combinations, which facilitates the marketing and production of cotton. The official classing of cotton, conducted by the Agricultural Marketing Service of the United States Department of Agriculture currently includes six quality attributes of the cotton lint: trash content, color, fiber length, micronaire, strength, and length uniformity. Two attributes, those being trash content and color, are encompassed in the grade. One component of trash content is bark. Under classing rules, the presences of bark in cotton results in the cotton being lowered one or two grades (e.g., grade 42 to grade 52 or grade 62), depending on the severity of the bark content. To the extent that bark presents a problem grade 52 or grade 62), depending on the severity of the bark content. To the extent that bark presents a problem which is different from the damage inflicted by other types of foreign material, this rule imposes a bark discount on the cotton which may (or may not) be arbitrary. One problem is that it is not known to what extent this loss in value to a producer is related to the decrease in the use value of the cotton.

Bark in cotton is not a new problem for the industry, but concern about it has increased with the industry's growing emphasis on quality fiber. All regions of the country have a problem with bark to some degree; however, the problem is most severe in the Southwest Region where cotton is predominantly machine stripped. Between 1967 and 1984, approximately 30% of the total bales harvested in the Southwest Region were reduced in grade due to bark. This compares to less than 5% in the other regions where cotton is predominantly machine picked (Ethridge and Neeper, 1986). In upland cotton, bark makes up more than 50% of the grade reductions associated with trash content in the United States (Anderson, 1991).

Even though the existence of bark in cotton can be related to stripper harvesting, the environment, cultural practices, seed variety, other harvesting practices, and other factors influence the degree to which bark occurs. However, these influences are not well understood, thereby making it difficult to correct for these problems. It may be noted however, that research done by Brashears (1984, 1985) on harvester modifications has been shown to reduce bark accumulation in the harvested cotton (Supak, 1989).

Bark in cotton causes three general problems for textile mills. First, bark in cotton increases waste loss in the initial cleaning of cotton in opening and carding. When bark is cleaned from the cotton lint, cotton fibers attached to bark, as well as bark itself, are lost. This decrease in total weight of cotton, from the loss of lint and bark during cleaning, is a loss in weight of cotton which was paid for. Second, bark that escapes the cleaning process may reduce spinning efficiency by increasing breaks in the yarn (i.e., ends down). Breaks in the yarn during spinning must be fixed, thereby increasing manufacturing costs. Third, bark can cause defects in the yarn and ultimately the fabric. Defects in the fabric are unappealing to consumers, and thus reduces the value of the yarn, fabric, or garment.

Given that the losses to textile processors from bark in cotton--the loss in use value--should be related to the loss in market value of cotton fiber which contains bark, it is important to understand, and hopefully quantify, the costs from bark in textile processing. Therefore, the objectives of this study were to:

1) estimate the costs to textile mills associated with processing cotton with various levels of bark, and
2) relate this cost back to the price of cotton.

Achieving these objectives should provide some insights on reasonable expected levels of market price discounts for bark.

Methods and Procedures

The method of estimating the cost of processing cotton with varying levels of bark was divided into two stages: total waste loss during opening and carding and breaks in the yarn during spinning. Opening and carding cotton is the stage where the cotton lint is separated, cleaned, and aligned. Most of the foreign material is removed from the cotton, but some amount of lint is also removed with the bark. The weight of the foreign material and cotton lint removed (i.e., total waste loss) was included in the cost of the bale of cotton. Therefore, the increase in total waste loss from cotton with no bark to cotton with bark was estimated, then a value (cost) was estimated for the waste loss caused by the bark.

In the spinning stage of processing, breaks in the yarn tend to increase with the amount of bark present in the cotton. There are two general types of spinning machines currently being used, rotor spinning machines and ring spinning machines. The rotor spinning machine uses centrifugal force and air to twist the cotton lint into yarn and wind it on spools. The ring spinning machine uses more moving parts and causes increased friction between the cotton lint and the machine as yarn is pulled, twisted, and wound onto spools. Therefore, using either machine, when breaks occur there is a cost involved in repairing it. Thus, the increase in breaks from cotton with no bark to cotton containing bark was estimated, then the increased cost from this loss in processing (spinning) efficiency was estimated.

The waste loss and processing efficiency data for this analysis were from three textile processing performance studies. One study, referred to as the "Price Study" (Price, 1991), provided fiber measurements and spinning tests on a sample of 16 bales of cotton, 12 of them designated as having sufficient bark to be reduced one grade due to excess bark, and four of them not reduced (not barky). The cotton used in that study had fiber properties, which varied only slightly in micronaire and grade, thus allowing the effects of the bark to be more isolated. The textile cleaning equipment used in that study was a modern single card machine, and the yarn was produced by rotor spinning. The spinning was conducted at a spindle speed of 90,000 rpm at a twist multiplier of 4.0 to produce a yarn count of 26.

Another study, referred to as the "Price and Shaw Study" (Price and Shaw, 1988), provided fiber measurements and spinning tests on a sample of 18 lots of cotton with each lot consisting of three bales of cotton. Six of the lots were designated as having zero bark content, where each bale had not been reduced in grade, six of the lots were designated as having medium bark content, where each bale had been reduced one grade due to bark, and six of the lots were designated as having heavy bark content, where each bale had been reduced one or two grades due to bark. Three of the lots having heavy bark content were tested under different textile processing conditions than the rest of the sample; therefore, these three lots were deleted from this analysis. The fiber properties of these lots were nominally the same, yet differing somewhat in micronaire, grade, and bark content. The cleaning equipment used in that study was an older single card, and both rotor and ring spinning were used to spin the yarn. The rotor spinning was conducted at a spindle speed of 90,000 rpm at a twist multiplier of 4.0 to produce a yarn count of 26. The ring spinning was conducted at a spindle speed of 11,000 rpm at a twist multiplier of 3.81 to produce a yarn count of 26.

The third study, referred to as the "Bragg et al. Study" (Bragg et al., 1991), provided fiber measurements and spinning tests on a sample of five different mixes of cotton. Two samples of cotton, one having low bark content graded Middling and the other having high bark content graded Strict Low Middling, were blended to make the five mixes of cotton. The mixes were 100% low bark content for mix 1, 75% low bark and 25% high bark for mix 2, 50% low and 50% high bark for mix 3, 25% low and 75% high bark for mix 4, and 100% high bark for mix 5. All the fiber properties of the cotton used in that study were consistent other than the grade. The cleaning equipment used in that study was an older single card, and the yarn was spun on a rotor spinning machine. The spinning was conducted at a spindle speed of 100,000 rpm at a twist multiplier average of 3.75 to produce a yarn count of 30.

In order to determine the economic losses associated with the weight losses, cotton prices were needed to establish the dollar value of a weight loss. Further, to put the processing cost losses in terms of producer prices, an adjustment was needed to account for the cost of moving the cotton, including the bark and wasted cotton (the waste loss), from farm to mill. Rather than calculate the various costs for transportation, insurance, handling, etc., and aggregate them, the simpler approach of estimating the margin was used. The margin, or difference between the price paid by processing firms and the price received by farmers, represents all costs between the two points. The farm price of cotton was calculated to be the average of all designated spot market prices for the years 1983 through 1988 for grades 31 and 41, staple 34, 3.5 through 4.9 micronaire (U.S. Department of Agriculture, 1989). The mill price of cotton was calculated as group 201 mill point prices for the same period and the same qualities (U.S. Department of Agriculture, 1989). The average marketing cost (margin) was estimated in this way to be 8.31 cents/lb.

The cost of a break in the yarn was used to quantify the increased cost of spinning yarn from cotton containing bark. The break cost data were provided by Schlafhorst, Inc. (Deussen, 1991). Deussen estimated the manufacturing cost per pound, production per machine per hour, and breaks per machine per hour for varying break rates. By taking the change in manufacturing cost times the production pounds per machine per hour divided by the breaks per machine per hour, he arrived at a cost per break. Deussen estimated the manufacturing costs, including all labor, capital, and operating costs, in the spinning room (excluding raw materials cost, overhead, and profit) for each break in rotor and ring spinning to be 0.6 cents and 3.0 cents, respectively.

The cost of bark in cotton beyond spinning, e.g., in finishing, dyeing, etc., were not quantified in this study. Information to establish any potential loss in value associated with any defects or additional weight losses was not available. Also, the waste accumulated during cleaning has some salable or reusable value to textile mills; however, these economic returns were likewise assumed to be zero in this study.

The basic approach used to estimate the effects of bark in cotton on textile processing costs were the same in all three studies. However, some specific points of analysis had to be modified because of the differences in experimental design among the processing studies.

To estimate the loss in value due to total waste loss in cotton, which is justified by a decrease in its value to the textile processor, the change in total waste loss from each bark designation for a selected producer price provides that estimate. This relationship can be specified as:

$$WC = \Delta W(P + MC) \quad (1)$$

where, WC = cost of bark to the textile processor in cents/lb. of cotton due to waste loss,
Δ = symbol for "change in,"
W = total (opening and carding) waste loss expressed as a percentage of weight of cotton,
P = producer price of cotton in cents/lb.,
MC = marketing cost in cents/lb. = $ 0.0831.

In the analysis, the producer prices of cotton selected were in five cents per pound increments from 50 to 75 cents per pound. This same approach for calculating waste cost was used for all the processing studies.

In the Price Study, the analysis found that there was a direct relationship between total waste loss and non-lint content. The relationship (Price, 1991) that most succinctly captures this effect is:

$$W = 5.007 + 0.769(Cn) \quad (2)$$

where, Cn = percent of non-lint content of the cotton. To estimate the total waste loss between the cotton containing bark and the non-bark content cotton in that study; the average non-lint content from each bark designation was taken to arrive at a total waste loss. The ΔW in equation 1 was the difference in the W in equation 2 between cotton with the Cn level of the barky cotton and the cotton with the Cn level of the non-barky cotton.

In the Price and Shaw Study, there was no significant difference in waste loss between the zero bark and medium bark cottons, so the ΔW between zero and medium bark was zero. (There was also no significant difference in average non-lint content values). The average change in total waste loss (ΔW) between medium bark and heavy bark was calculated directly from the average waste in medium and heavy bark.

In the Bragg et al. Study, the analysis found that there was also a direct relationship between total waste loss and non-lint content. The linear relationship that captures this effect is:

$$W = 3.086 + 0.59(Cn) \quad (3)$$

The ΔW for equation 1 was calculated in the same manner as in the Price Study, except that four ΔW's were computed using equation 3 rather than just one.

The other processing problem attributable to bark, with the exception of the Price Study, was the increased number of breaks. In the Price Study, there was no significant difference in spinning breaks between barky and non-barky cotton. Consequently, with that cleaning process, there was no processing efficiency cost.

In the Price and Shaw Study, there was a significant relationship between total waste loss and the yarn break rates on both rotor and ring spinning machines. The relationships were:

$$Fr = [e^{(4.40 + 0.48 W)}]/1000 \quad (4)$$
$$Fg = [e^{(1.77 + 0.61 W)}]/1000 \quad (5)$$

where, Fr = rotor spinning break rate per spindle hour,
e = symbol for exponential = 2.7183,
Fg = ring spinning break rate per spindle hour.

To estimate the break rate per spindle hour, the average total waste loss for each of the bark levels was used to get the Fg and Fr for the respective bark levels. Once the break rate per spindle hour was estimated, this value was converted to breaks per pound of clean cotton processed per spindle hour. The following formula provides the estimated pounds of clean cotton processed per spindle hour.

$$PP = (R * H) / (504 * Y^{1.5} * T) \quad (6)$$

where, PP = pounds of clean cotton processed per spindle hour,
R = spindle speed in revolutions per minute (rpm),
H = spindle hours,
Y = yarn count = number of hanks of 840 yards which weigh one pound,
T = twist multiplier = turns per inch per square root of yarn count.

To estimate the cost of breaks in spinning to raw cotton, i.e., the form producers sell the cotton in, the amount of clean cotton processed per spin hour had to be divided by the total waste loss percentage to get the cotton back to a raw pounds estimate. That calculation is encompassed in the formula to estimate the break cost per pound. To determine the cost of bark in cotton attributable to breaks in the different bark designated cotton, the following relationship can be specified.

$$BC = (D * \Delta F) / [PP / (1 - W)] \qquad (7)$$

where, BC = break cost, in cents per pound of cotton,
D = cost of one break for designated type of spinning, in cents per break,
F = spinning break rate per spindle hour (i.e., Fr or Fg).

The break rates per spindle hour (F) from the Bragg et al. Study were taken directly from the data rather than from a relationship such as equation 4; the number of observations were too small to estimate a relationship. The break costs per pound of cotton were calculated using equations 6 and 7 in the same manner as in the Price and Shaw Study, except that four BCs were computed rather than two.

To determine the full loss in value attributable to the different levels of bark in the cotton in each of the three studies, the two costs, i.e., the waste cost (WC) and break cost (BC), were summed to obtain the textile processing costs attributable to varying levels of bark in cotton:

$$TC = WC + BC \qquad (8)$$

where, TC = total cost of bark attributable to each bark content designation.

Results

The results of this analysis provide an estimate of the loss in use value (costs) to textile processors for processing cotton with various bark designations on different types of processing equipment. In the Price Study, where the cotton was cleaned on modern cleaning equipment, it produced greater average total waste losses than in the other two studies (Table 1). Consequently, the modern cleaning equipment seemed to be more thorough in removing the bark content and thus the average change in total waste loss was greater. Since there was such a significant amount of waste loss, the loss in use value is also a substantially large cost when compared to the other studies. The loss in use value associated with bark in cotton ranged from 1.27 to 1.77 cents per pound of cotton (Table 2).

In the Price and Shaw Study, the average total waste losses were less than in the Price Study, which may be attributed to the use of older cleaning equipment. The average change in total waste loss was not significantly different from zero between zero and medium bark designations; however, the change is evaluated in this study because the cotton was reduced one grade due to the presence of bark in the cotton. Since there was such a small change in the average total waste loss, the cost associated with the waste loss was also small, ranging from 0.09 to 0.13 cents per pound of cotton. The average change in total waste loss for heavy bark was significant, but still only about half that of the Price Study. Thus, the loss in use value due to total waste loss in heavy bark designated cotton ranged from 0.72 to 1.02 cents per pound, approximately half that of the Price Study.

In the Bragg et al. Study, the average total waste losses were comparable to the Price and Shaw Study at the lower and upper bounds. In that study, the cotton was also cleaned on older cleaning equipment; consequently, the average total wastes range from approximately 4 to 5 percent of the total weight. The loss in use value of the mixes progressively increases from a range of 0.11 to 0.15 cents per pound of cotton in mix 2 to a range of 0.43 to 0.61 cents per pound of cotton for mix 5.

Overall the added textile processing costs, i.e., loss in use values, attributable to total waste loss appear to range from 1.27 to 1.77 cents per pound of cotton, where the cotton is cleaned on more modern cleaning equipment. Cotton cleaned on older cleaning equipment, the added processing costs attributable to total waste loss range from 0.43 to 1.02 cents per pound of cotton. Both ranges of added processing costs relate to cotton that had been reduced one to two grades.

The resulting losses in use value due to losses in spinning efficiency complement the waste cost results. In the Price Study, there was no significant loss in spinning efficiency; therefore, there was no break cost for spinning the cotton containing bark. However, it may be noted that the modern cleaning equipment provided greater waste loss, leaving no bark in the cotton to produce significant spinning efficiency losses.

In the Price and Shaw Study, the cottons producing the total waste losses were divided and spun on both rotor and ring spindles. The results between zero and medium bark cotton are again statistically insignificant. The results of the cotton spun on a rotor spinning machine seem to show significant, but small, changes in average break rates (Table 3). The large difference in the economic losses in processing performance can be related back to the average change in break rates for the two bark designations.

Cotton spun on a ring spinning machine show a much greater impact of bark on spinning efficiency. The break rate almost doubled for heavy bark versus medium bark cotton. The loss in use value for medium bark cotton using ring spinning machines was estimated to be 0.56 cents per pound of cotton. The increased cost for heavy bark cotton due to breaks during spinning was estimated to be 6.39 cents per pound of cotton. This shows that cotton with a significant amount of bark, cleaned on older equipment and spun on ring spinning machines, will cause a substantial loss in processing efficiency.

In the Bragg et al. Study, where only rotor spinning was used, the results were similar to those in the Price and Shaw Study. The average change in break rates increases incrementally through the different mixes. The loss in use value associated with spinning efficiency ranged from 0.11 to 0.33 for mix 2 through mix 5, respectively. The small added processing cost due to breaks in the study as compared to the Price and Shaw Study can be associated with the fact that mix 1 is low bark content, not no bark content, and a greater amount of waste was removed.

The total added textile processing cost, for selected producer cotton prices proved to be relatively consistent across processing studies (Table 4). The upper bark designations in each study, excluding ring spinning, indicates that the total added processing cost is approximately 1 to 2 cents per pound of cotton. When heavy bark contamination exists and ring spinning is used, the total added processing cost is approximately 7 to 7.5 cents per pound of cotton.

Conclusions

The results of this study show a wide range of added textile processing costs for various bark content cottons, due largely to differences in type of cleaning equipment, spinning technology, and bark categories. Cotton reduced one grade and cleaned on modern cleaning equipment seems to eliminate the problems caused by bark in the spinning process. However, the greater total waste loss from more effective cleaning offsets the negligible spinning efficiency loss in terms of overall costs to the textile processor.

The evidence on losses incurred from bark in ring spinning versus rotor spinning examined in this study is limited, but it suggests that losses from bark in ring spinning processes are substantially greater than in rotor spinning, at least when older cleaning equipment is used and bark contamination is heavy. Overall, bark losses in textile processing are small except when bark contamination is heavy.

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Table 1. Summary of Waste Losses (as % of total weight) in Selected Situations

Situation	Bark Designations				
Modern cleaning equipment (Price Study)	No Bark				Bark
Waste Loss (%)	7.998				10.121
Change in Waste Loss (%)			2.123		
Older Cleaning Equipment (Price and Shaw Study)	No Bark		Medium Bark		Heavy Bark
Waste Loss (%)	4.39		4.54		5.62
Change in Waste Loss (%)		0.15		1.23	
Older Cleaning Equipment (Bragg et al. Study)	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5
Waste Loss (%)	4.31	4.50	4.68	4.86	5.05
Change in Waste Loss (%)	0.18	0.37	0.55	0.73	

Table 2. Added Textile Processing Costs from Waste Loss, in cents/lb. of Lint Cotton, Based on Selected Processing Studies

Producer Cotton Price	Bark Designations						
	Price Study	Price and Shaw Study		Bragg and et al. Study			
	Bark	Medium Bark	Heavy Bark	Mix 2	Mix 3	Mix 4	Mix 5
	cents/lb.						
50	1.27	0.09	0.72	0.11	0.21	0.32	0.43
55	1.34	0.10	0.78	0.12	0.23	0.35	0.46
60	1.45	0.10	0.84	0.13	0.25	0.38	0.50
65	1.56	0.11	0.90	0.13	0.27	0.40	0.54
70	1.66	0.12	0.96	0.14	0.29	0.43	0.57
75	1.77	0.13	1.02	0.15	0.30	0.46	0.61

Table 3. Summary of Processing Performance (in terms of breaks per spindle hour) as Affected by Bark

Situation	Bark Designations					
Price and Shaw Study:						
Spindle Type	Rotor Spinning			Ring Spinning		
Bark Designations	Zero	Medium	Heavy	Zero	Medium	Heavy
Average Break rates	0.6652	0.7148	1.1958	0.0868	0.0952	0.1843
Change in Average Break rates		0.0496	0.5305		0.0084	0.0975
Added Processing Cost from loss in processing performance (cents/lb. of cotton)		0.08	0.89		0.56	6.39

Situation	Rotor Spinning				
Bragg et al. Study:					
Spindle Type	Rotor Spinning				
Bark Designations	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5
Average Break rates	0.270	0.330	0.380	0.390	0.455
Change in Average Break rates		0.060	0.110	0.120	0.185
Added Processing Cost from loss in processing performance (cents/lb. of cotton)		0.11	0.20	0.21	0.33

Table 4. Added Textile Processing Costs, in Cents per Pound of Producers' Cotton, Associated with Bark in Cotton

Producer Cotton Price	Bark Designations								
	Price Study	Price and Shaw Study				Bragg et al. Study			
	Rotor Spinning	Rotor Spinning		Ring Spinning		Rotor Spinning			
	Bark	Medium	Heavy	Medium	Heavy	Mix 2	Mix 3	Mix 4	Mix 5
	cents/lb.								
50	1.27	0.17	1.61	0.64	7.10	0.21	0.41	0.53	0.75
55	1.34	0.18	1.67	0.65	7.17	0.22	0.43	0.56	0.79
60	1.45	0.19	1.73	0.66	7.23	0.23	0.45	0.59	0.83
65	1.56	0.19	1.79	0.67	7.29	0.24	0.46	0.62	0.86
70	1.66	0.20	1.85	0.67	7.35	0.25	0.48	0.64	0.90
75	1.77	0.21	1.91	0.68	7.41	0.26	0.50	0.67	0.94