ECONOMIC ANALYSIS OF USING CRUSTACEA BYPRODUCTS FOR THE COVERAGE OF NEPS

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Abstract

An economic analysis is conducted on a textile process which uses chitosan and is designed to cover neps while dyeing cotton yarns and fabrics in textile mills. The benefits examined include reduced dye use and reduced rejection of fabrics, while the costs examined include the cost of the chitosan, costs of associated chemicals, additional labor, and variable and fixed overhead costs. The estimated benefits and costs are considered in various scenarios to determine potential cost effectiveness. Results indicates that chitosan treatments are not cost effective for textile mills to adopt at this time.

Introduction

The Texas economy relies heavily on cotton production. In 1993, producers in the Southern High Plains of Texas (SHPT) produced 52 percent of the state's 5,095,000 bales of cotton (United States Department of Agriculture, 1995). The SHPT consists of the counties of Andrews, Bailey, Cochran, Crosby, Dawson, Gaines, Glasscock, Hockley, Howard, Lamb, Lubbock, Lynn, Martin, Midland, Terry, and Yoakum. Cotton produced within this region is used by textile mills throughout the world.

Cotton is the most commonly used natural textile fiber in the world, accounting for about 50 percent of total world fiber production. Cotton represents about 38 percent of all fibers used in apparel, 18 percent in home furnishings, and about 12 percent of the fibers used in industrial products (Starbird et al., 1987). The quality of cotton determines whether cotton is used to produce apparel or home furnishings. Cotton with a higher quality is used for clothing, while lower quality cotton is used for household or industrial products.

Cotton produced in the SHPT has a reputation for being of low quality, generally having a low micronaire and a high percentage of small knots or fiber entanglements known as neps. Neps appear as white specs on the surface of dyed cotton fabric and are caused by immature fibers which become entangled. This low quality is caused primarily by the short growing season, cool night temperatures and early freezes resulting in cotton not maturing properly. The problem of neps is one reason for fabric rejection. Rejection of the fabric at the dyeing stage is expensive because of the cost of the value-added processes from production through processing. Because neps cannot be removed from the fiber, processors generally must use one of several treatments to enable the fabric to receive the dye uniformly.

One treatment used for the coverage of neps involves the use of a cationic polymer pretreatment by the pad/dry process (Mehta et al., 1990). This treatment is effective in covering neps when dyeing with direct, reactive and acid dyes. However, because this treatment is based on the pad/dry method, the fabric must be dried after scouring and/or bleaching prior to its application. An alternative to the pad/dry treatment is based on the exhaust method, which eliminates a drying process and is easily incorporated into most fabric preparation sequences already being used (Mehta and Combs, 1990). One treatment which uses the exhaust method involves the use of a derivative of chitin.

Chitin is the second most plentiful, naturally occurring polymer, after cellulose, in the world. Chitin is found in the exoskeletons of arthropods. For commercial uses this product is primarily derived from shrimp and crabs. Chitosan, a derivative of chitin, is prepared by partial deacetylation of the chitin. Chitin and chitosan have a variety of special functions ranging from health and beauty aids to water purification, biomedical applications, agriculture, biotechnology, nutrition, and treatments in the finishing process of textile fibers. Chitosan is also used in a process which covers neps in cotton fabrics, which is the subject of this analysis.

The fiber containing neps is pretreated with a mixture of chitosan, a non-ionic wetting agent, and sodium sulfate (hereafter referred to as chitosan treatment). The chitosan treatment requires no additional machinery and increases the dyeing ability of direct and reactive dyes. This treatment is also effective in eliminating differences in color between dyed immature and mature cotton fibers (Rippon, 1984). The binding of the chitosan with the cellulose already present in the cotton fiber increases the fiber's dyeing ability and reduces problems resulting from immature or entangled fibers that will not accept dye, thereby reducing the impact of the quality problem most SHPT producers must deal with.

Chitosan is biodegradable when used and distributed into the environment in a dispersed fashion. Thus, using chitosan treatments in the textile dyeing process represents an environmentally sound practice (Mehta 1996). With the introduction of chitosan treatments for cotton yarns and fabrics, the primary problem caused by neppiness can be overcome.

A limitation of the chitosan treatment is that it enhances the performance of some dyes better than others. Chitosan treatments, used in conjunction with direct dyes, increase the color strength more than reactive dyes (Mehta, 1996). An additional problem with the chitosan treatment is that it

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reduces the quality of the wash-fastness and/or color-fastness properties, but this is alleviated with the introduction of a post treatment consisting of fiber-reactive quaternary ammonium compounds (Rippon, 1984). However, this additional requirement adds to the already numerous stages through which mills must place their yarns without any assurances that their efforts will pay off.

Most textile processors are slow to adopt new and unknown practices. Because chitosan treatments are unfamiliar to many textile processors, they are reluctant to adopt these practices, thereby not potentially maximizing their profits. Processors should be made aware of the potential economic benefits and costs of this treatment.

The objective of this study was to conduct a benefit cost-analysis of the use of the chitosan treatment for cotton yarns and fabrics. Issues such as decreased use of dye and decreased rejection of fabrics at the mill are considered.

Methods and Procedures

Estimation of the cost effectiveness of adoption of the chitosan treatment was accomplished by conducting a benefit/cost analysis for the use of the chitosan treatments in a representative mill setting. Estimated cost values from the dyeing process of a representative mill are included in Table 1. This representative mill is assumed to be a medium sized textile mill, which uses between 18,000 and 22,000 bales of cotton per year to produce apparel and furniture upholstery. It is assumed that approximately 80 percent of this cotton is used to produce light weight fabrics for apparels and the remainder is used for household and industrial upholsteries.

Textile mills often spin cotton into yarn, weave the yarn into fabric, and dye the fabric only to find that it is unsuitable for use in the final product because of the presence of neps. It is assumed that the representative mill has a rejection rate of 3.5 percent of the fabric. It is further assumed that 10 percent of this rejection is due to the presence of neps. Thus, it is assumed that 0.35 percent of the light weight fabric is rejected due to the presence of neps. If the textile mill were to adopt chitosan treatments, a decrease in the percentage of fabric rejection would be a benefit of this treatment. It is assumed that textile mills generally will not purchase a lower quality cotton merely because the chitosan treatment would allow for the coverage of neps with dye. The purchase of a lower quality cotton would lead to a lower quality finished product.

Cost-effectiveness of the chitosan treatment is determined by whether benefits outweigh costs. The major benefits examined in this study are the reduction in use of dye and the decrease in the amount of fabric rejected due to the presence of neps. The amount of the reduction in dye used will depend on the depth of color preferred, which will affect the amount of dye used.

Costs considered in the adoption of the chitosan treatment in a textile mill are: the cost of the chitosan, cost of additional chemicals (sodium sulfate and non-ionic wetting agent), cost of additional labor, and additional overhead expenses, both variable (water, electricity, opportunity costs) and fixed.

The cost of adopting chitosan treatments can be expressed in the following form:

$$TC = CCH + CWA + CSS + VOH + FOH + CAL.$$

Where TC is the total cost of the chitosan treatment, CCH is the cost of the chitosan, CWA is the cost of the non-ionic wetting agent, CSS is the cost of sodium sulfate, VOH is the increase in variable overhead, FOH is the increase in fixed overhead, and CAL is the increase in cost of labor. The total benefits are expressed in the following form:

$$TB = VDD + VDR.$$

Where TB is the value of the total benefits received from the adoption of the chitosan treatment, VDD is the value of the decrease in the amount of dye used, and VDR is the value of the decrease in fabric rejection. The economic efficiency of adopting chitosan treatments is determined by whether TB is greater than TC, or if net returns (NR) are greater than zero, where NR = TB - TC.

Results

Treatment Costs

Table 1 presents the estimated costs of three wet processes from a representative textile mill. This data was supplied from an actual mill setting. To protect the anonimity of the mill, the identification will not be disclosed. The first procedure for which data is presented is a bleach formula process. Yarn treated by this process will be used in white fabrics only. These values are expressed in dollars per pound of yarn. The total cost of putting yarn through the bleaching process was found to be $0.14990 per pound of yarn. This total cost consists of labor, variable overhead (which includes water and electricity), fixed overhead (representing a percentage of the firm's fixed costs), and chemical costs. Also in Table 1 are the various costs for putting a yarn through a process that involves scouring, not bleaching, and being dyed black. Scouring is a process in which the fabric or yarn is cleansed, using detergents and soaps, and either an abrasion or rubbing treatment. This process is used to remove dirt, grime, soil and other foreign matter or particles. The final process presented in Table 1 is a process in which the yarn is scoured and bleached, then dyed red. The bleach process is less expensive than the other two representative processes because it requires less time to complete the process and there are no dye costs associated with this process. The bleaching process requires approximately 90 minutes to complete, while the dyeing processes requires an additional 40 to 50 minutes.

Table 2 presents the various costs associated with the chitosan treatment. Chitosan prices depend on the quantity purchased. Venson, Inc. provided prices for chitosan. If less than 50 pounds is purchased, the price of the chitosan is $15 per pound. This price decreases to $10 per pound when the amount purchased is between 50 and 499 pounds. The price is further reduced to $8.50 per pound and $8 per pound when the amount purchased is between 500 and 2000 pounds and over 2000 pounds, respectively. Pricing is available at a lower cost per pound when contracting to annually purchase larger quantities over a multi-year period.

The amount of cotton processed in the representative mill is assumed to be 18,000 bales per year (bale weight is 480 pounds). This represents 8,640,000 pounds of cotton lint processed annually. Given that the amount of chitosan used is 0.4 percent on the weight of the cotton, and assuming that the representative mill uses 80 percent of that cotton to produce light weight fabrics, the expected amount of chitosan needed annually is 27,648 pounds (e.g. 18,000 bales * 480 pounds per bale * 0.8 * 0.004). Thus, the representative mill qualifies to enter into a contract with the chitosan supplier to receive a lower price. Because these lower prices are not known, the cost effectiveness of the treatment is initially determined using a cost of $8 per pound for chitosan. However, this cost is later reduced for further analysis.

The chemical costs for the chitosan treatment are determined by the amount of chitosan used, the price of chitosan and the prices of associated chemicals. The amount of non-ionic wetting agent used is 0.1 percent on the weight of the yarn, and the amount of sodium sulfate (Glauber salt) used is 10 percent on the weight of the yarn. The price of sodium sulfate is $0.22 per pound, and the price of the non-ionic wetting agent is $0.89 per pound.

The time required for the chitosan treatment is assumed to be represented in the fixed overhead costs. Water and electricity used in this process is represented in the variable overhead costs. The bleach process previously presented takes an average of 90 minutes to complete. Because the chitosan treatment takes approximately 30 minutes, it is assumed that one chitosan treatment will require one-third of the labor costs, and one-third of the variable and fixed overhead costs specified for the bleach process. Thus, given the data contained in Table 2, the estimated cost of the chitosan treatment is approximately $0.10 per pound of yarn.

<u>Treatment Benefits</u>

As stated previously, one of the benefits recognized from the use of the chitosan treatment is the reduction of the amount of dye used. For direct and reactive dyes, the chitosan treatment can reduce the amount of dye required by ten percent. The reduction in the amount of dye used is based on the K/S value which measures the color value, or strength of the dye (Mehta and Combs, 1990). The average cost of direct dyes is approximately $7 per pound, and reactive dyes cost an average of $17 per pound (Mehta 1996). The amount of dye used depends on the desired depth of color. For a moderate shade of any color, the general amount of dye used is approximately 2 percent of the weight of the yarn. Thus, two pounds of dye is used to dye 100 pounds of cotton yarn.

The average amount of dye required to dye one pound of cotton a moderate shade of any color is 0.02 pounds. Assuming the use of a direct dye, the use of chitosan treatments will decrease the required amount of dye by ten percent. Therefore, the amount of dye required to dye one pound of yarn after chitosan treatments, is .018 pounds. Assuming the use of a direct dye, the benefit in decreased use of dye resulting from the adoption of the chitosan treatment is 1.4 cents per pound of cotton (e.g. $7/lb * (.02-.018)).

Another benefit received from adopting the chitosan treatment is the decrease in the rejection of fabric due to the problem of neps. The representative mill is assumed to process 6,912,000 pounds of cotton per year for use in apparels (i.e., 18,000 bales * 480 pounds per bale * 80 percent). It is assumed that the representative mill is producing yarn as a blended product of numerous qualities of raw cotton lint. This yarn is assumed to be homogeneous. Therefore, the mill is assumed to treat all yarn used in apparels with the chitosan process in order to receive the 10 percent reduction in the 3.5 percent fabric rejection. Thus, with a 3.5 percent fabric rejection, it is assumed that the mill rejects 241,920 pounds of fabric per year. It is further assumed that ten percent of this is rejected due to the presence of neps (i.e. 24,192 pounds). The chitosan treatment is assumed to be able to prevent the rejection of this 10 percent of the 3.5 percent rejected fabric. The mill is assumed to measure the cost of this rejection in terms of linear yards of fabric. The representative mill receives an average of $3.25 for each linear yard of finished fabric. They sell their rejected fabric in a secondary market for an average of $1.25 per linear yard. Therefore, the loss due to rejection is $2.00 per linear yard of fabric rejected. Assuming a light weight yarn of 5 ounces per square yard of fabric, and a 60 inch fabric width, one linear yard of fabric contains 0.52 pounds of cotton. The 24,192 pounds of rejected fabric represents 46,523 yards of fabric. This fabric has a loss due to the presence of neps of $2.00 per yard. Therefore, the loss in value of the rejected fabric is $93,046. Thus, given this value of the use of the chitosan treatment, the value per pound of cotton treated is $0.0135 per pound of cotton (i.e., $93,046/6,912,000 pounds of cotton). Therefore, the adoption of chitosan treatments will yield a 1.35 cent benefit per pound of cotton due to the reduction of rejected fabric.

The cost for adopting chitosan treatments is approximately 10 cents per pound of cotton. The combined benefits received from reduced fabric rejection and when using direct dyes are 2.75 cents per pound (i.e., \$0.0140 + \$0.0135), and 4.75 cents per pound (i.e., \$0.0340 + \$0.0135) when using reactive dyes. Thus, the benefits of the chitosan treatments do not outweigh the costs of implementing this process in textile mills.

Sensitivity Analysis

Tables 3 through 7 present the net revenues associated with adoption of chitosan treatments when primary benefits and costs are varied. The net revenue values in Table 3 result from allowing the costs of both chitosan and sodium sulfate to decrease in 10 percent intervals, while the cost of dyes are increased from \$7 per pound, the cost of direct dyes, to \$17 per pound, the cost of reactive dyes. The process continues to not be economically feasible when we decrease costs (i.e., the combined cost of chitosan and sodium sulfate is decreased by as much as 50 percent) and increase benefits (i.e., the cost of dye is increased by 143 percent).

Table 4 presents the net revenues when the costs of labor, variable overhead, and fixed overhead are all decreased in 10 percent intervals, while the assumed reduction in rejection of fabric is increased from 10 percent to 15 percent. Again the process does not appear to be cost effective. The net revenue values in Table 5 are estimated as a result of decreasing the cost of chitosan from the current \$8.00 per pound to \$4.00 per pound while increasing the value of rejected fabric from \$2 per linear yard to \$3.25 per linear yard. The process is not cost effective in this scenario. Table 6 provides net revenues when the cost of the entire chitosan treatment is decreased, while the value of the rejected fabric increases, and Table 7 lists the net revenues when the cost of the chitosan treatment is varied, while the cost of the dye is increased. Thus, this process is not shown to be cost effective in any scenario considered. Therefore, given the current economy and technologies, the chitosan treatment is not found to be cost effective.

Discussion

Although the adoption of chitosan treatments is not cost-effective for the representative mill considered in this study, different textile mills may incur different costs. Therefore, the following equations were developed to allow textile mills to determine whether the treatments would be cost effective for their specific mill situation. Net revenues (NR) of adoption is the difference between total benefits and total costs. The following cost equation is offered:

$$TC = .004 * CC + .001 * CWA + .1 * CSS + VOH + FOH + CAL$$

Where TC is the total cost of the chitosan treatment per pound of cotton treated, 0.004 is the amount of chitosan used on the weight of the fabric, CC is the cost of the chitosan (\$8/lb), 0.001 is the amount of non-ionic wetting agent used on the weight of the fabric, CWA is the cost of the non-ionic wetting agent (\$0.89/lb), 0.1 is the amount of sodium sulfate used on the weight of the fabric, CSS is the cost of sodium sulfate (\$0.22/lb), VOH and FOH are the variable and fixed overhead costs of the textile mill for running one bath process for approximately 30 minutes, and CAL is the cost of additional labor required to run the bath.

The following benefit equation is offered:

$$TB = [0.1*QD*CD + \{[(PR*RR*TFD)/.52]*VF\}/TFD]$$

Where TB is the value of the total benefit from the adoption of the chitosan treatment per pound of cotton treated, 0.1 is the reduction in the use of dyes, QD is the quantity of dye used per pound of cotton, CD is the cost per pound of dye used, PR is the percent of fabric rejected because of neps, RR is the percentage reduction in fabric rejection due to the adoption of chitosan treatments, TFD is the total fabric dyed, 0.52 is the pounds of cotton per linear yard of fabric, and VF is the difference in value of the fabric which would have been rejected if chitosan treatments were not used.

Conclusion

Chitosan treatments are not cost effective for the representative mill within this study. This cost effectiveness is based on many assumptions which could vary among other textile mills. Therefore, a textile mill interested in adopting chitosan treatments is encouraged to use the above relationships to determine whether the chitosan treatment would be cost effective for that particular textile mill.

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Table 1. Costs for various textile processes in a representative mill ($/lb of yarn).

Process	Labor	Var OH[1]	Fixed OH[2]	Dyes	Chems	Total Cost
Bleach	0.0322	0.0692	0.0344	0.0000	0.0141	0.1499
Black[3]	0.1710	0.3671	0.1826	0.4896	0.1646	1.3749
Red[4]	0.1569	0.3367	0.1675	0.0979	0.0901	0.8491

[1] Var OH represents costs of variable inputs such as electricity, water, and others not described elsewhere.
[2] Fixed OH represents costs of fixed inputs as well as time required for the prices.
[3] Scoured, not bleached.
[4] Scoured and bleached before being dyed.

Table 2. Input costs for chitosan treatment.

	Cost/lb	Amount Used	Cost/lb of cotton
Chitosan	$8.00	0.4% o.w.y.*	$0.0320
Sodium Sulfate	$0.22	10% o.w.y.*	$0.0220
Non-ionic Wetting Agent	$0.89	0.1% o.w.y.*	$0.00089
Labor			$0.0107
Variable Overhead Costs			$0.0231
Fixed Overhead Costs			$0.0113
Total Cost of Process			$0.0999

* On weight of yarn.

Table 3. Net Revenues When Cost of Chitosan and Sodium Sulfate Decrease by 10% With Increasing Cost of Dyes.

Dye Cost	Reduction in Cost of Chitosan and Sodium Sulfate Base*	10%	20%	30%	40%	50%
7	-.0725	-.0671	-.0617	-.0563	-.0509	-.0455
8	-.0705	-.0651	-.0597	-.0543	-.0489	-.0435
9	-.0685	-.0631	-.0577	-.0523	-.0469	-.0415
10	-.0665	-.0611	-.0557	-.0503	-.0449	-.0395
11	-.0645	-.0591	-.0537	-.0483	-.0429	-.0375
12	-.0625	-.0571	-.0517	-.0463	-.0409	-.0355
13	-.0605	-.0551	-.0497	-.0443	-.0389	-.0335
14	-.0585	-.0531	-.0477	-.0423	-.0369	-.0315
15	-.0565	-.0511	-.0457	-.0403	-.0349	-.0295
16	-.0545	-.0491	-.0437	-.0383	-.0329	-.0275
17	-.0525	-.0471	-.0417	-.0363	-.0309	-.0255

*The base price of chitosan is $8/lb., base price of sodium sulfate is $0.22/lb.

Table 4. Net Revenues When the Costs of Labor, Variable Overhead, and Fixed Overhead are reduced by 10% For Different Reductions in Fabric Rejections.

PercentR ejected	Reduction in Costs of Labor, Variable, and Fixed Overhead Base*	10%	20%	30%	40%	50%
10	-.0725	-.0680	-.0635	-.0590	-.0544	-.0499
11	-.0711	-.0666	-.0621	-.0576	-.0531	-.0486
12	-.0698	-.0653	-.0608	-.0563	-.0518	-.0472
13	-.0684	-.0639	-.0594	-.0549	-.0504	-.0459
14	-.0671	-.0626	-.0581	-.0536	-.0491	-.0445
15	-.0658	-.0612	-.0567	-.0522	-.0477	-.0432

*Base costs of labor, variable, and fixed overhead are $0.0107, $0.0231, and $0.0113, respectively.

Table 5. Net Revenues Increasing Costs of Chitosan and Increasing Value of Rejected Fabric.

Chitosan Price	Value of Rejected Fabric ($/linear yard) 2.00	2.25	2.50	2.75	3.00	3.25
7.00	-.0725	-.0708	-.0691	-.0674	-.0658	-.0641
7.50	-.0705	-.0688	-.0671	-.0654	-.0638	-.0621
7.00	-.0685	-.0668	-.0651	-.0634	-.0618	-.0601
6.50	-.0665	-.0648	-.0631	-.0614	-.0598	-.0581
6.00	-.0645	-.0628	-.0611	-.0594	-.0578	-.0561
5.50	-.0625	-.0608	-.0591	-.0574	-.0558	-.0541
5.00	-.0605	-.0588	-.0571	-.0554	-.0538	-.0521
4.50	-.0585	-.0568	-.0551	-.0534	-.0518	-.0501
4.00	-.0565	-.0548	-.0531	-.0514	-.0498	-.0481

Table 6. Net Revenues With Decreasing Costs of Chitosan Treatments With Increasing Values of Rejected Fabrics.

Value of Fabric	Cost of chitosan treatments ($/lb of cotton treated) 0.10	0.09	0.08	0.07	0.06	0.05
2.00	-.0725	-.0625	-.0525	-.0425	-.0325	-.0225
2.25	-.0708	-.0608	-.0508	-.0408	-.0308	-.0208
2.5	-.0691	-.0591	-.0491	-.0391	-.0291	-.0191
2.75	-.0674	-.0574	-.0474	-.0374	-.0274	-.0174
3.00	-.0658	-.0558	-.0458	-.0358	-.0258	-.0158
3.25	-.0641	-.0541	-.0441	-.0341	-.0241	-.0141

Table 7. Net Revenues With Decreasing Costs of the Chitosan Treatments and Increasing Cost of Dyes.

Dye Cost	Cost of chitosan treatment ($/lb of cotton treated) 0.10	0.09	0.08	0.07	0.06	0.05
7	-.0725	-.0625	-.0525	-.0425	-.0325	-.0225
8	-.0705	-.0605	-.0505	-.0405	-.0305	-.0205
9	-.0685	-.0585	-.0485	-.0385	-.0285	-.0185
10	-.0665	-.0565	-.0465	-.0365	-.0265	-.0165
11	-.0645	-.0545	-.0445	-.0345	-.0245	-.0145
12	-.0625	-.0525	-.0425	-.0325	-.0225	-.0125
13	-.0605	-.0505	-.0405	-.0305	-.0205	-.0105
14	-.0585	-.0485	-.0385	-.0285	-.0185	-.0085
15	-.0565	-.0465	-.0365	-.0265	-.0165	-.0065
16	-.0545	-.0445	-.0345	-.0245	-.0145	-.0045
17	-.0525	-.0425	-.0325	-.0225	-.0125	-.0025