The *Journal of Cotton Science 19:298–306 (2015)*
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ECONOMICS AND MARKETING

Evaluating Cotton Utilization in Nonwoven Textiles

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ABSTRACT

Fabrics made from weaving and knitting yarns constitute the largest part of textiles manufactured around the world, but various nonwoven technologies constitute the fastest growing sector of textiles. This study evaluates the potential for cotton fiber in nonwoven textiles and analyzes the issues of cotton use in nonwovens, with a focus on potential target markets. Data were collected through an online survey conducted among the global companies producing nonwoven products. Cotton is not being used by most nonwoven producing firms. Polypropylene and rayon are the primary substitute fibers. Reasons for using the substitute fibers include price, price volatility, and processing costs of cotton. The willingness to use more cotton is evident for products requiring absorbency and especially in products for personal hygiene. The factors constraining cotton consumption in nonwovens are primarily economic in nature rather than technological.

Nonwovens are engineered textile substrates that are made directly from fibers and other polymers bonded together by chemical, mechanical, heat, or solvent treatments. These exclude fabrics made by spinning or extruding yarns and then weaving or knitting fabrics. There are great differences in textile production methods between traditional and nonwoven textiles. Nonwoven technologies are generally, very capital intensive, with very high throughputs, limited labor requirements, and lighter in area produced by weight (Lichstein, 1988; Albrecht et al., 2005; Kellie, 2013). These factors combine to result in relatively lower production costs per unit of output compared to traditional textiles. The diverse raw materials combine with diverse manufacturing technologies to enable great variety in end products. Nonwoven textiles are found in a wide variety of products, either as a component or as a distinct product. There is an increasing number of new nonwoven products produced related to medical and personal care, filters and electronics, clothing/household textiles, padding/laminated textiles, geotextiles, and other technical textiles.

Nonwoven textiles are made with both natural and man-made materials, which include polypropylene, polyester, nylon, rayon, cotton, wood pulp, and blends of these fibers (Sawhney and Condon, 2009). The man-made fibers account for approximately 95% of total fiber usage in nonwovens, which is about 6.426 million metric tons (Kellie, 2013). Polypropylene, polyester, and rayon are the major fibers that are used in production of nonwoven textiles (INDA and EDANA, 2008; Moreau, 1990). By 2012, polypropylene demand for nonwoven textile was an estimated 1.16 million metric tons, which is 21% higher than in 2007 (INDA and EDANA, 2008). Limited information is available about uses of natural fibers, including cotton, in nonwovens. Sawhney and Condon estimated that cotton fibers account for about two percent of all fiber in nonwoven products (Sawhney and Condon, 2008; Sawhney, 2015). Further, INDA projected 35,000-40,000 metric tons of cotton would be consumed in nonwoven textiles by 2012 (INDA and EDANA, 2008).

Man-made fibers dominate in nonwovens, often for use with specific nonwoven technologies (Krcma, 1971). Some of the dominant nonwoven technologies are designed for thermoplastic man-made fibers. These fibers may be designed explicitly for targeted technologies and products.

A limited number of studies have been done on the feasibility of using natural fibers, especially cotton, in combination with other fibers to produce nonwoven textiles. For example, a study conducted by Sun, Zhang, and Wadsworth used

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thermal bond technology to develop cotton-based nonwovens, with polypropylene staple fiber as a bonding material containing 60%, 50%, and 40% of cotton, to analyze bonding temperature and strength of the nonwoven product (Sun et al., 2000). Wadsworth, Suh and Allen reported use of cotton in laminated fabrics to produce short-wear cycle apparel, with excellent wetting, wicking rates, water adsorption, flexibility, and extensibility (Wadsworth et al., 2000). Kamath, Bath, and Mueller concluded that natural fibers have the ability to form bonds between thermoplastic binder polymers (Kamath et al., 2005). Kinzel concluded that at least ten percent synthetic fiber is required to use thermal bonding techniques; but that 100% cotton nonwoven products could be produced using needlepunch and hydro-entanglement technologies (Kinzel, 1991). Parikh et al. concluded that gauze made from hydro-entanglement cotton nonwovens have better aesthetic and physical characteristics than does traditional woven gauze (Parikh et al., 1999). Sawhney et al. concluded that absorbency of greige cotton in nonwovens can be controlled by optimizing the processing parameters such as water pressure in hydro-entanglement technology (Sawhney et al., 2010). Mueller and Krobjilowski determined that cotton-based composites have good acoustical properties (Mueller and Krobjilowski, 2003). Jiang et al. and Parikh et al. showed that nonwovens with a cotton surface have superior sound absorption and noise reduction properties (Jiang et al., 2009; Parikh et al., 2006). Sekine et al. developed a metal adsorbent nonwoven product containing cotton by graft polymerization (Sekine et al., 2010). Previous studies have shown that utilization of cotton in nonwoven textiles is technically feasible with some of the dominant nonwoven technologies and a subset of nonwoven textile products made with these technologies that benefit from cotton's fiber properties. But the fact is that cotton utilization remains quite small in nonwoven textiles.

A consumer survey conducted in the United States (U.S.) among 500 respondents by Barnhardt Manufacturing and AC Nielsen in 2004 showed that 80% of people would view cotton favorably in baby wipes for attributes like softness, naturalness, and absorbency; and 79% of mothers would prefer natural fibers, among which 63% would pay more for baby wipes containing cotton (Mclntyre, 2005). Ahlstrom, PGI Nonwovens, Jacob Holm Industries, and Unitika are some of the nonwoven producing companies that have produced cotton-based nonwoven products in various product categories such as hygiene, medical, absorbents, insulation for houses, etc. (Mclntyre, 2006). Absorbent and hygienic products, wipes, and medical and healthcare products are the fastest growing market segments in nonwoven textiles where cotton has higher probability for utilization. Consumer awareness of health benefits and the attributes of absorbency and hygiene are the key variables for future growth of cotton use in these products. In 2007, global hygiene product consumption was 1.41 million metric tons, equivalent to 27% of total nonwoven production in that year, and it was estimated that by 2012 this share would increase to 29% (INDA and EDANA, 2008). Instead of cotton, almost all these products are being produced using fibers like viscous rayon, polylactic acid (PLA) resins and other man-made fibers.

The share of nonwoven textiles in global textile production is not large; however, it is one of the fastest growing sectors. Between 1997 and 2011, the nonwoven textile market increased from $11 billion to $26 billion in sales equivalent to 2.7 million metric tons and 7.6 million metric tons respectively, and an annual growth rate of 6.2% in dollars or 7.7% in metric tons. It is projected to grow at an annual rate of 7.8% between 2011 and 2016 (INDA and EDANA, 2012). The major producers of nonwoven products are the United States, Western Europe, and Japan. The number of U.S. firms producing nonwovens increased from 29 to 45 between 1998 and 2000 (Woon and Peter, 2002).

The prices of alternative fibers greatly impacts cotton's share of the nonwovens market. The price of polyester has stayed lower and is less volatile compared to cotton over the decades (Plastina, 2010; Fadiga and Misra, 2007). In 2010/11, cotton price volatility reached a record high (Plastina, 2012). Future volatility in cotton price depends heavily upon Chinese cotton policy and their large stocks of cotton (roughly 50% of world stocks). Cotton price volatility complicates the business planning process for textile manufacturers as they must price finished products for downstream contracts but purchase a raw product with significant price volatility. Thus, especially in recent years, cotton has been disadvantaged by significantly higher price volatility.

There have not been any significant studies addressing opportunities and limitations for cotton in nonwoven textiles other than studies about the technological aspects of cotton use. The objective of this study is to evaluate the potential for cotton fiber in nonwoven textiles in general and analyze the issues of cotton use/non-use in nonwovens. The specific objectives are to:

1. assess various products and technologies that use cotton in order to obtain information on potential target markets, and
2. identify the issues that motivate or deter the use of cotton among the nonwoven textile producers.

METHODS

An online survey of global nonwoven textile producing firms was designed in 2011 and conducted during 2012. Cotton fiber opportunities and limitations were evaluated based on responses and descriptive statistics to provide insight into the nonwovens inputs, technologies and end products categories.

Survey design. The survey was designed in consultation with experts who are familiar with the nonwoven textile industry and several pre-survey tests were done by nonwoven manufacturers. The questionnaire consisted of both open- and closed-end questions. Based on responses to preparative questions, the questionnaire had different branches and multiple levels. A schematic diagram of the design of the questionnaire is shown in Figure 1 (Luitel, 2012). Most of the questions were designed as categorical with either single choices (e.g., yes/no) or multiple responses (e.g., "Which of the following products do you produce?"). In some questions, an '*others*' choice accompanied the opportunity for further explanation while, in some questions a '*don't know'* choice was made available. Rank order questions were also included. In ranking questions, respondents were asked to partially rank the top three choices from a list. Typically, asking respondents to rank more than three choices results in inefficient responses (Caplan et al., 2002).

Questionnaire. The questionnaire started with an introductory section to identify cotton-using firms. This was followed with firm production information and reasons for fiber choices. The questionnaire was ended with a hypothetical question regarding the future of cotton in their firm.

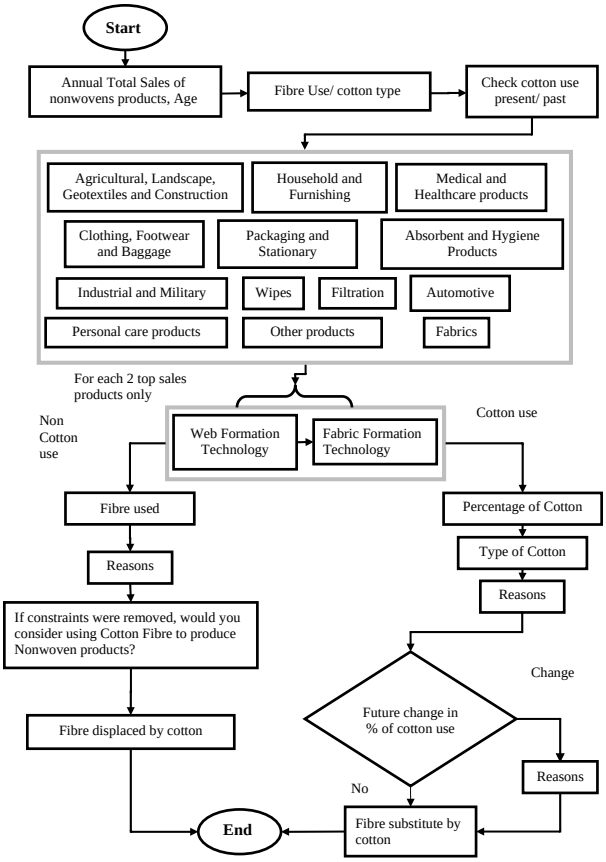

Figure 1 Flow chart for Structure of the questionnaire

The introduction section consisted of questions regarding age of the firm and approximate sales to determine the firm's size. The fibers used in the production of nonwoven products were identified and the status of cotton use (i.e., current "cotton using", "formerly cotton using", and "non-cotton using") was established. Based on the firm's cotton use status, tailored sets of questions were asked for each category of firms: 1) the response from "cotton using" firms focused on cotton-based nonwoven products, 2) the response from "formerly cotton using" firms focused on products they used to produce previously using cotton, and, 3) the response from "non-cotton using" firms focused on products they produce with different fibers. The questions consisted of identifying the top two end-product categories based on sales. For each product category, technologies and fiber used was obtained. Following the answer on products and technologies, reasons for the use/non-use of cotton was evaluated by a ranking of the top three reasons among five/six available alternatives. Finally, respondents were also asked to identify the substitute fibers for cotton and future prospect regarding utilization of cotton.

Survey administration. '*Survey Monkey'*, an online survey-conducting platform was used in this study. The questionnaire was pre-tested by six different individuals to estimate the time of completion and clarity of the questions. On average, it took ten to fifteen minutes for an individual to complete the questionnaire.

Rodman publishing is one of the leading sources of information regarding the global nonwoven industry; it also publishes a magazine that is widely recognized among nonwoven textile producers called *Nonwoven Industry Magazine*. This firm was contracted to deliver this survey to those firms in its global database of magazine subscribers. The survey was delivered to two major target groups of subscribers: roll goods manufactures and end products manufacturers. The survey was launched on Feb. 8, 2012 and a reminder was sent on March 7, 2012. The survey was closed on April 5, 2012.

Survey response and data. The response rate was 32.15% from 762 respondents, who opened the survey. The survey resulted in 245 total valid responses, consisting of 118 end products manufacturers and 127 roll goods manufacturers. On average, respondents had been in the nonwoven products production business for 26 years. The younger firms tended to be non-cotton users, while the older firms tended to be former cotton users. Firms currently using cotton, approximately 30% of the respondents (Table 1), had been in business an average of 29 years.

There are limited numbers of firms that account for most of the nonwoven production in the world; however, these firms typically have multiple subsidiaries. The result was multiple responses from subsidiaries of a single conglomerate firm. Among 58 respondents that self-identified their firms, only 19 separate firms were represented. However, the reality of multiple subsidiaries means that multiple responses from same name firms do not imply a duplication of product information. The products produced by the roll goods manufacturers are used as inputs by the end product manufacturers. Therefore, most of the results in this study only use responses from the end-product manufacturers.

RESULTS

Fiber used. Most of the respondents used polypropylene (76.3%) and polyester (75.5%) as raw materials to produce nonwoven products (Table 1). This result is consistent with world consumption of polyester and polypropylene, which consist of around 60% of total staple fiber consumption by weight in nonwoven textiles (INDA and EDANA, 2008). These were followed by rayon (43.7%) and cotton (31.0%). Responses from cotton-using firms indicate very few cotton-only nonwoven products are produced. Cotton fiber is most often used either in combination with other fibers or to make specific part of a product.

The 31% of the respondents currently using cotton fiber were asked to identify the shares of cotton use attributable to virgin cotton, waste cotton, and reclaimed cotton[1]. On average, percentages of the total cotton used as virgin cotton, waste cotton, and reclaimed cotton was 69.9%, 19.4% and 10.8%, respectively. Applying these percentages to the INDA (INDA and EDANA, 2008) projection for 2012, specific cotton fiber consumption may comprise 28,000 metric tons of virgin cotton, 7,600 metric tons of waste cotton and 4,400 metric tons of reclaimed cotton.

1 Definition of each of these was provided in the survey.
Virgin cotton: Cotton fibres that have not gone through recycling or reprocessing.
Waste cotton: Cotton fibres are regarded as waste during the ginning and textile manufacturing processes, which are collected and prepared for other uses.
Reclaimed cotton: Cotton fibres are obtained by converting processed yarns and fabrics back to a fibrous state and preparing these for other uses

Table 1. Response for fiber used in production of nonwoven products from total survey.

Fiber used in production of nonwoven products	Percentage response (%)[Z]
Polypropylene	76.3
Polyester	75.5
Rayon	43.7
Cotton	31.0
Polyamide	30.2
Others	30.6
Acrylic	25.3

[Z] Total percentage may not add to 100%

Nonwoven products. The three largest categories of products identified as being produced were absorbent and hygiene products, wipes, and medical and healthcare products (Table 2). Taken together, these products were in the product mix for 59.6% of the respondents. An additional 12.2% indicated filtration products, with all other percentages falling below six percent.

For absorbent and hygiene products, 38.6% of the responses came from "current cotton using" and "formerly cotton using" firms, while 59.0% came from "non-cotton using" firms. For wipes and medical and healthcare products, 44.83% and 55.56% of responses came from current and past users of cotton and 55.17 % and 40% came from firms that did not use cotton, respectively. Thus, only medical and healthcare products had a majority of the respondents indicating the use of cotton.

The dominant fiber in absorbent and hygienic products was identified as polypropylene. The dominant fiber in filtration products is polyester. For wipes, the dominant fiber is rayon. The reasons given for cotton use in these product categories are cotton's physical properties and marketing advantages.

Technologies used. Carding, Spunlaid, and Airlaid were the most frequently used web formation technologies (Table 3). Thermal bonding, Hydro-entanglement, and chemical were the most frequently used web bonding technologies (Table 4). For those making cotton-based products, 53.0% used carding for web formation; for non-cotton based products 46.8% used carding. For those making cotton-based products, 33.3% used thermal bonding for web formation; for non-cotton based products 66.7% used thermal bonding. For Hydro-entanglement technology, these percentages were 42.0% and 58.3%, respectively. The importance of Spunlaid technology is expected to increase, due to increasing capacities being installed in China and India (INDA and EDANA, 2008). For most nonwoven products, it is technically feasible to use some proportion of cotton with all of these technologies.

Table 2. End product manufacturing firm's response for nonwoven products.

Nonwoven products produced (n=156)[Y]	Percentage response[Z]
Absorbent and Hygiene Products	25.0
Wipes	18.6
Medical and Healthcare products	16.0
Filtration	12.2
Household and Furnishing	5.8
Industrial and Military	5.8
Fabrics	4.5
Personal care products	3.9
Automotive	3.2
Agricultural, Landscape, Geotextiles and Construction	2.6
Clothing, Footwear and Baggage	1.9
Other products	0.6
Packaging and Stationery	0.0

[Y]Including primary and secondary products.

[Z]Total percentage may not add to 100%

Table 3. End product manufacturers' response for web formation technology.

Web Forming Technology (n=156)[Y]	Percentage response
Carded	30.1
Spunlaid (Spunbonded)	24.4
Airlaid	21.8
Meltblown	14.1
Other(co-form, spunlace)	5.1
Wetlaid	4.5

[Y]Including primary and secondary products.

Table 4. End product manufacturers' responses for web bonding technology

Web bonding Technology (n=156)[Y]	Percentage response
Thermal Bonding	30.8
Spunlace (Hydro-entanglement)	23.1
Chemical Bonding	18.6
Needlepunching	15.4
Other(co-form, laminating, hydrogen bonding)	7.1
Stitch bonding	5.1

[Y]Including primary and secondary products.

In web formation, cotton fibers must perform against the man-made fibers to participate in the fiber mixes; as all the web formation technologies can use cotton in production in different proportion. In case of web bonding, it seems likely that thermal bonding and chemical bonding allow very limited use of cotton fibers, while 100% use of cotton may be concentrated in the needle punching and hydro-entanglement technologies. These results are consistent with those obtained by Kinzel (1991).

Table 5 provides more information about the correspondences of fibers used with the different technologies and products. Carding and Hydro-entanglement technologies were the most commonly cited as used to produce cotton-based nonwoven products and are the most frequently used technologies in the sample. Information provided by both "cotton using" and "formerly cotton using" firms allowed the identification of potential opportunities for cotton fiber utilization with some specific nonwoven products and technologies (Table 5). Clearly, cotton and rayon use the same technologies (carding and hydro-entanglement) to produce the same products (absorbent and hygiene). This corroborates the assumption that these are close substitutes in nonwovens. But the fact is that 36% of the cotton-using firms indicated that the share of cotton in the fiber mix was one to nine percent. This share is consistent with the use of cotton in thermal bonding technology (Kinzel, 1991), which was indicated as frequently as was hydro-entanglement technology.

Substitute fibers for cotton. Most of the respondents (54.6%) considered rayon to be a close substitute for cotton, followed by polyester and polypropylene (Table 6). Rayon is a man-made cellulose fiber with properties more similar to cotton than are polyester and polypropylene. While not indicated in Table 6, the responses for substitute fibers were quite similar among roll goods manufacturers and end products manufacturers.

Reasons for using and not using cotton. The "natural" characteristic is a primary incentive for using cotton. Marketing features were the most frequently cited reason to use cotton in the production of nonwoven products (Table 7). Its marketing features include being 'natural' and providing a 'premium product'. This was closely followed by physical properties, which contribute directly to consumers' attitudes about cotton (Mclntyre, 2005). However, 84% of the respondents did not want to increase cotton's share in the fiber mixes to produce nonwoven products, while 16.7% anticipated removing cotton from the mixes in the future.

In those cases where cotton use was discontinued, the most frequently cited reason was 'change in production cost', followed by 'change in demand' and 'price volatility' (Table 7). In the survey, 'change in production cost' was described as high fiber price, high processing cost, and technological constraints compared to substitute fibers. Using cotton in production incurs additional processing cost from increased filtration and waste disposal. In the survey, 'change in demand' was described as price competition with substitute products. The "change in demand" for the cotton products may have been cited in part because of historically high and volatile cotton prices during the time of the survey[2]. In addition to a short-term response along existing demand and supply curves, this extraordinary episode may have also shifted the longer term demand and supply for cotton.

2 Cotton prices increased for a short time to about $2.00 per pound, which was 2.5 to 3 times the historical levels. The spot market annual average price for cotton was 137.88 cents for 2010-2011 season, while it was 85.81 cent for 2011-2012 season (USDA, 2012).

Table 5. Responses for different fibers regarding technology use and product produced

Fiber used	Most frequent response for each fiber		
	Web Forming Technology	Web bonding Technology	Nonwoven products
Polypropylene	Spunlaid(spunbond) (47.4%)	Thermal (63.2%)	Absorbent and hygiene (44.7%)
Polyester	Carding (39.3%)	Needlepunch (28.6%)	Filtration (17.9%)
Polyamide	Spunlaid(spunbond) (50.0%)	Thermal (50.0%)	Filtration (50.0%)
Rayon	Carding (50.0%)	hydro-entanglement (62.5%)	Absorbent and hygiene (37.5%)
Cotton	Carding (36.2%)	Thermal (23.2%) Hydro-entanglement (21.7%)	Absorbent and hygiene (21.7%), Medical and healthcare (21.7%) Average cotton % on Products (36.2% of response use 1-9% cotton on Products)
Others	Airlaid (63.6%)	Chemical (45.5%)	Wipes (36.4%)

Table 6. Total survey responses regarding substitute fibers for cotton

Substitute fiber (n=245)	Percentage response
Rayon	54.7
Polyester	19.6
Polypropylene	18.8
Other	4.1
Acrylic	2.0
Polyamide	0.8

Table 7. Responses from firms regarding reasons for different cotton use status[Z].

Reason for Using cotton (n=76)	Reason for stop using cotton (n=41)	Reason for never using cotton (n=128)
Marketing features (27.3%)	Change in production cost (23.8%)	Products don't need cotton (27.0%)
Physical properties (22.7%)	Change in demand (18.5%)	Change in production cost (21.5%)
Price advantage (16.7%)	Price Volatility (13.3%)	Change in demand (10.2%)
Reliable source (14.0%)	Introduction of new fiber (10.5%)	Others (8.8%)
Others (3.7%)	Difficulty in procurement (10.0%)	Price volatility (8.5%)
	Others (9.5%)	Difficulty in procurement (6.5%)

[Z] Total percentage may not add to 100%, Weighted average of the top 3 rank order choices was calculated. Weighted average = (3* Rank 1 + 2* Rank 2 + 1* Rank 3) / 6

The reasons for never using cotton were similar to those for stopping the use of cotton, except the most frequently given reason was that 'products don't use cotton'. This partly reflects the growth of technologies based on continuous processes that integrate the fiber and fabric formation because the use of staple fibers is not compatible with these technologies.

Among the "formerly cotton using" firms, 29% indicated a willingness to consider using cotton in the future, primarily due to the marketing advantages and the properties of cotton fibers. These reasons were also similar to those firms currently using cotton and those who expect to increase cotton use. The corresponding response among the "non-cotton using" firms for willing to

use cotton was 46%, if the technical and economic constraints were removed.

DISCUSSION

The largest single category of nonwoven textiles is for personal care and hygiene products. The short life cycles (many are single-use products) enable large production volumes and reliable revenue flows. Cotton fiber properties are excellent for these types of products and are compatible with some of the major technologies used to produce them. However, three major factors work against cotton taking larger shares of these markets:

- **Technology:** Even though most of the nonwoven production technologies could use cotton, they have been developed with a focus on using manufactured fibers, so the technologies are generally more 'friendly' to these fibers. Furthermore, the manufactured fibers are continually being modified (different sizes, shapes, molecular structures, etc.) to provide additional functionalities for diverse nonwoven textile products. There is much less potential for making such modifications on cotton fiber.
- **Production Cost:** Bleached, rather than raw, cotton is preferred in the production of nonwoven textiles. This entails additional processing (cleaning, scouring, bleaching, and filtering, followed by treatment of the resulting waste water). All of these processes entail increased costs and production delays, which disadvantages cotton in the mass production of most nonwoven textiles.
- **Price:** Regarding price, factors of weather, seasonal production, and policy-induced distortions in the market create uncertainty about price level and price stability for cotton fiber. Polyester dominates in many nonwoven textiles and its prices have generally been lower and less volatile than cotton prices. Manufactured fiber price may be fixed extending weeks or even months into the future, thereby alleviating the need for hedging the risk of price changes. (Thus, even a higher price for these fibers may be offset by the lower cost of risk management.) For polyester, the large global excess production capacity ensures a stable supply, while the finite land area that is devoted to cotton production is subject to significant variations based on competition for the land from other agricultural products. Moreover, when cotton supplies get tight, the nonwoven textile manufacturers risk becoming a 'residual buyer' because the manufacturers of higher-value, durable woven and knitted textiles will pay more for the cotton they need.

CONCLUSION

The superior fiber properties and the premium market image of cotton provide a marketing advantage. The survey clearly revealed that this is the major justification for nonwoven manufacturers to utilize cotton.

Nonwovens for which cotton clearly has demand-driven advantages versus substitute fibers, are absorbent and hygienic products, medical/surgical and health care products, personal care products, and wipes. Cotton has the required fiber properties such as absorbency, superior comfort, disposability, and sanitation value. Also, the technologies used to produce these products are generally compatible with cotton. Even in these categories, however, the aforementioned economic factors constrain its use. A major implication to take from this study is that technical feasibility of using cotton fibers in nonwoven textiles is currently insufficient to incentivize significant increases in the use of cotton.

Recommendation. The issues to be resolved for cotton to increase its share in nonwoven textiles revolve around alleviating these limiting factors. Adjustments in the marketing system that facilitated forward contracting might be a way to improve cotton's competitive position. A complementary effort to improve the marketing system could be developing improved ways to incorporate preprocessed cotton fibers into the system. Perhaps genetic engineering or other means to develop cotton varieties specifically for nonwoven applications could be undertaken. Currently all efforts in these arenas are focused exclusively on cotton's use-value in yarn spinning. Without breakthroughs in these arenas, cotton appears destined to remain a niche fiber in nonwoven textiles.

ACKNOWLEDGEMENTS

Supported by USDA-NIFA grant through the International Cotton Research Center; and the Texas Department of Agriculture [grant numbers NFR 11 03].

The authors would like to thanks David Strack, CEO of Product Imaginengineering, for his assistance in preparing the questionnaire.

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