EVALUATING COTTON UTILISATION IN NONWOVEN TEXTILES

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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 fibre in nonwoven textiles and analyses the issues of cotton use in nonwovens, with a focus on potential target markets. Data was collected through an online survey conducted among the global companies producing nonwoven products. Results show that cotton is not being used by most nonwoven producing firms and polypropylene and rayon are the primary substitute fibres. Reasons for using the substitute fibres 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.

Keywords:
Cotton, Nonwovens Textiles, Technical Textile, Cotton Properties for Nonwoven Use.

Nonwovens are engineered textile substrates that are made directly from fibres 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. Nonwoven textiles are found in a wide variety of products, either as a component or as a complete product, most of which are found in products related to medical and personal care, filters and electronics, clothing/household textiles, padding/laminated textiles, geotextiles, and others. 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). According to the volume growth rate recorded for nonwovens during the period 1990 - 2000, production was projected to increase at an annual rate of 5-7% through 2010 (Kiekens and Zaamfir, 2002). The European Disposables and Nonwovens Association (EDANA) and The Association of the Nonwoven Fabrics Industry (INDA) the production of nonwoven roll goods reached 5.75 million tonnes globally in 2007, with a market value of $20.9 billion. Between, 2007-2012, world production of nonwovens was projected to grow at 7.9%, reaching 8.41 million tonnes by 2012 (INDA and EDANA, 2008).

Nonwoven textiles are distinct from woven textiles due to low production cost, high manufacturing speed and wide spectrum of raw materials and products properties, (Lichstein, 1988; Albrecht et al., 2005). Nonwoven textiles are made with both natural and man-made materials which include polypropylene, polyester, nylon, rayon, cotton, wood pulp, and blends of these fibres (Sawhney and Condon, 2009). Man-made fibres dominate in nonwovens, often for use with specific nonwoven

technologies (Krcma, 1971). Polypropylene, polyester, and rayon are the major fibres that are used in production of nonwoven textiles (INDA and EDANA, 2008; Moreau, 1990). By 2012, polypropylene demand from nonwoven textile was estimated at1.16 million tonnes, which is 21% higher than in 2007 (INDA and EDANA, 2008).

The price of the polyester has stayed lower and 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, cotton price volatility could be a significant deterrent to its use in nonwovens.

Nonwoven technologies can use customised fibre to produce end products. This may explain why most studies in the nonwoven textiles literature have focused on developing new artificial fibres. But some studies have been done on the feasibility of using natural fibres, especially cotton, in combination with other fibres to produce nonwoven textiles. For example, a study conducted by Sun, Zhang, and Wadsworth used thermal bond technology to develop cotton based nonwovens, with polypropylene staple fibre as a bonding material containing 60%, 50%, and 40% of cotton, to analyse 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 fibres have good ability to form bonds between thermoplastic binder polymers (Kamath et al., 2005). Kinzel concluded that at least 10 percent synthetic fibre is required to use thermal bonding techniques; but that 100% cotton nonwoven products could be produced using needlepunch and spunlaced technologies (Kinzel, 1991). Parikh et al. concluded that gauze made from spunlaced 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 optimising the processing parameters such as water pressure in spunlaced technology (Sawhney et al., 2010). Mueller and Krobjilowski determined that cotton-based composites have remarkably 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 polymerisation (Sekine et al., 2010).

Previous studies suggest that utilisation of cotton in nonwoven textiles is technically feasible with some of the dominant nonwoven technologies. Also, there is a subset of nonwoven textile products made with these technologies that well exploit cottons fibre properties. But the fact is that cotton utilization remains quite small in nonwoven textiles.

Sawhney and Condon estimated that cotton fibres account for about 2% of all fibre in nonwoven products (Sawhney and Condon, 2008). Further, INDA projected 35,000-40,000 tonnes of cotton would be consumed in nonwoven textiles by 2012 (INDA and EDANA, 2008). A consumer survey conducted among 500 respondents by Barnhardt Manufacturing and AC Nielsen in 2004 showed that 80% of people would view cotton favourably in baby wipes for attributes like softness, naturalness, and absorbency; and 79% of mothers would prefer natural fibres, 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 utilisation.

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, hygiene product consumption was 1.41 million tonnes, equivalent to 27% of total nonwoven production in that year, and was estimated that by 2012 this share would increase to 29% (INDA and EDANA, 2008). However, almost all these products are being produced using fibres like viscous rayon, PLA resins and others man-made fibres.

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 fibre in nonwoven textiles in general and analyse the issues of cotton use/non-use in nonwovens. The specific objectives are to:

1) Assess various products and technologies that uses cotton in order to obtain information on potential target markets, and

2) Identify the issues that motivate and 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 fibre 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 up to the top three choices from a list.[1]

QUESTIONNAIRE

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

The introduction section consisted of questions regarding age of the firm and approximate sales to determine the firm's size. The fibres 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 fibres. The questions consisted of identifying the top two end-product categories based on sales. For each product category, technologies and fibre 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. At the end, respondents were also asked to identify the substitute fibres for cotton and future prospect regarding utilisation 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 understandability of the questions. On average, it took 10-15 minutes for an individual to complete the questionnaire and the questions were readily understood.

Rodman publishing is one of the leading sources of information regarding the global nonwoven industry; it also publishes a magazine that is widely recognised among nonwoven textiles producers called *Nonwoven Industry Magazine*. This firm was

[1] Typically, asking respondents to rank more than three choices results in inefficient responses (Caplan et al., 2002).

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.

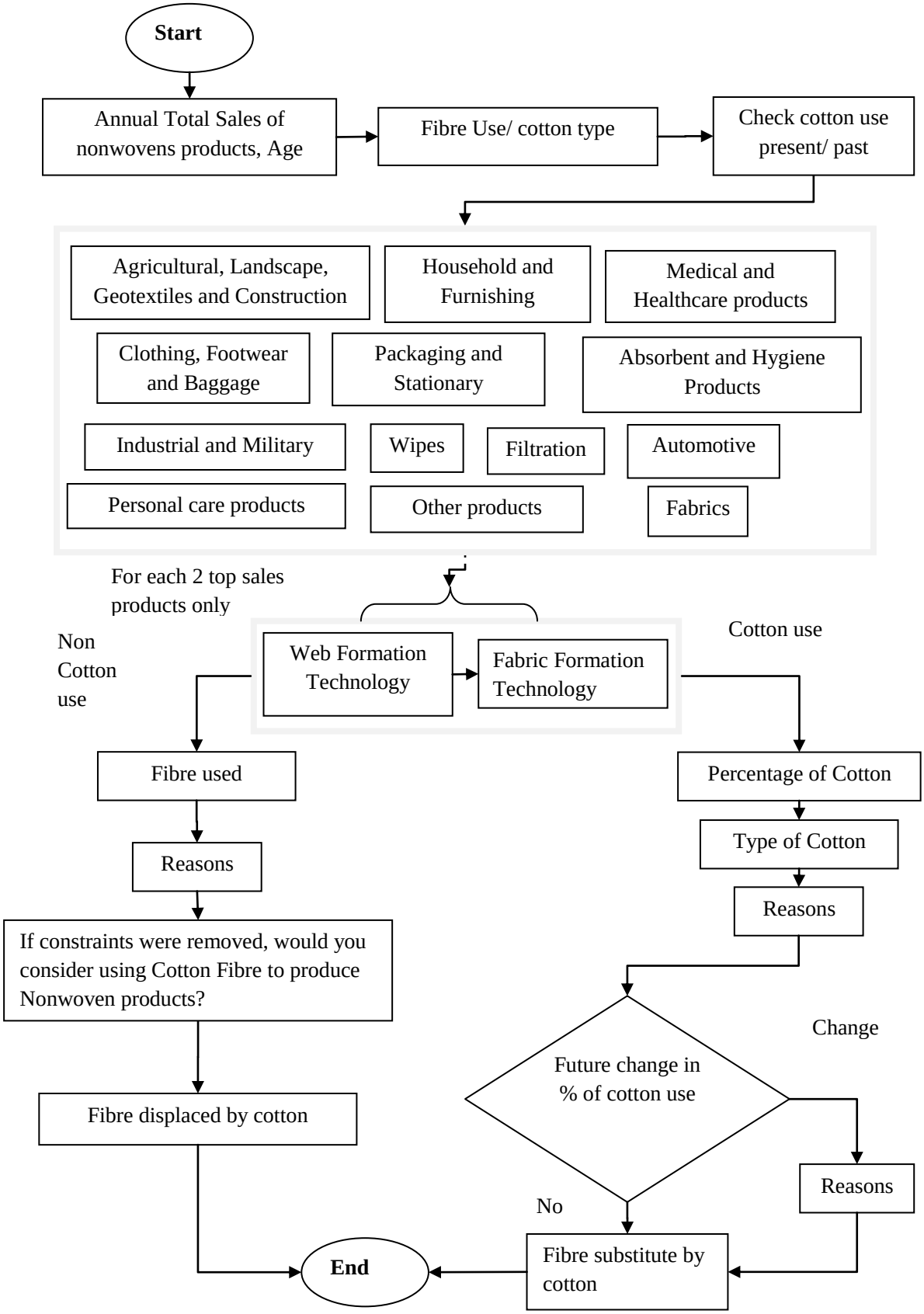

Figure 1. Flow chart for structure of the questionnaire

SURVEY RESPONSE AND DATA

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. There are limited numbers of firms that account for most of the nonwoven productions 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 most useful responses came from the end-product manufacturers, because products produced by the roll goods manufacturers are used as inputs by the end-product manufacturers.

RESULTS

FIBRE USED

According to the responses, 30% of firms are classified as current “cotton using” firms (Table I). Most of the respondents used polypropylene (76.3%) and polyester (75.5%) as raw materials to produce nonwoven products. This result is consistent with world consumption of polyester and polypropylene, which consist of around 60% of total staple fibre consumption 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 fibre is most often used either in combination with other fibres or to make specific part of a product.

Table I. Response for fibre used in production of nonwoven products from total survey

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

[a] Total percentage may not add to 100% due to multiple-fibre use.

The 31% of the respondents currently using cotton fibre were asked to identify the shares of cotton use attributable to virgin cotton, waste cotton, and reclaimed cotton[2]. A weighted average was calculated in two steps. First, the average percentage of each type of cotton was calculated. Secondly, the weighted average of each type of cotton was calculated by multiplying the response rate for the corresponding average percentages across all respondents and dividing by the total number of responses. The resulting 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 fibre consumption may comprise 28,000 tonnes of virgin cotton, 7,600 tonnes of waste cotton and 4,400 tonnes of reclaimed cotton.

NONWOVEN PRODUCTS

The three largest categories of products identified as being produced were absorbent and hygiene products, wipes, and medical and healthcare products (Table II). 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 6%.

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, 44.8% of responses came from current and past users of cotton and 55.2% came from firms that did not use cotton. For medical and healthcare products, these percentages were 55.6% and 40.0% respectively. Thus, only medical and healthcare products had a majority of the respondents indicating the use of cotton.

The dominant fibre in absorbent and hygienic products was identified as polypropylene. The dominant fibre in filtration products is polyester. For wipes, the dominant fibre is rayon. The reasons for using cotton in all product categories where cotton was used were cotton’s physical properties and marketing advantages.

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

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

Nonwoven products produced (n=156[a])	Percentage response
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

[a] including Primary and secondary products.

TECHNOLOGIES USED

Carding, spunlaid, and airlaid were the most frequently used web formation technologies (Table III), while thermal bonding, spunlaced, and chemical were the most frequently used web bonding technologies (Table IV). Carding was used by 53.0% for cotton-based products, while 46.8% used it for non-cotton based products. Thermal bonding was used by 33.3% for cotton-based nonwoven products, while 66.7% used it for non-cotton based products. For Spunlaced 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, cotton could be used in some proportion with all of these technologies.

Carding and spunlaced 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 fibre utilisation for some specific nonwoven products and technologies (Table V). Cotton based medical and healthcare products are produced using spunlaid (40.0%), and thermal (26.7%) technologies. Absorbent and hygiene products are produced using polypropylene fibres (70.8%) with spunlaid (45.8%) and thermal (50.0%) technologies. Both types of products used similar technologies and cotton has the potential to be substituted for polypropylene. The reality, however, is that polypropylene is predominantly used instead of cotton use in these nonwoven products.

Table III. End-product manufacturers' response for web formation technology

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

[a] including Primary and secondary products.

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

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

[a] including Primary and secondary products.

SUBSTITUTE FIBRES FOR COTTON

Most of the respondents (54.6%) considered rayon to be a close substitute for cotton, followed by polyester and polypropylene (Table VI). Rayon is man-made cellulose fibre, whose properties are more similar to cotton than polyester and polypropylene. While not indicated in Table VI, the responses for substitute fibres were quite similar among roll goods manufacturers and end-products manufacturers. Among respondents using rayon, the most frequently produced products were absorbent and hygiene products (Table V). These were predominantly produced using carding and spunlaced technologies.

Table V. Responses for different fibres regarding technology use and product produced

Fibre used	Most frequent response for each fibre		
	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%)	Spunlaced (62.5%)	Absorbent and hygiene (37.5%)
Cotton	Carding (36.2%)	Thermal (23.2%) Spunlaced (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 VI. Total survey responses regarding substitute fibres for cotton

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

REASONS FOR USING AND NOT USING COTTON

The "natural" characteristic is a primary incentive for using cotton. Marketing factors were the most frequently cited reason to use cotton in the production of nonwoven products (Table VII). Its marketing advantages include being 'natural' and providing a 'premium product'. Further, consumer preference for cotton for its feel, being natural fibre, or any other intangible reason adds marketing value to product having cotton fibre. It also has certain physical properties (melting temperature, absorbency, and density) that also motivate "cotton using" firms to choose it for products that need these properties. Further, from the above literature, consumers prefer cotton-based products (Mclntyre, 2005).

However, 84% of the respondents did not want to increase the quantity of cotton they are using in their production of nonwoven products. Furthermore, 16.7% of the respondents said they would shift from cotton using to a non-cotton using status in the future. The most frequently cited reason for these firms to end the use of cotton was 'higher production costs' compared to substitute fibres, followed by 'change in demand' and 'price volatility' (Table VII). Using cotton in production incurs additional processing (e.g., filtration cost of trash contained in cotton fibre), which increases the cost of production due to increased handling and waste. 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.[3] 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.

The reasons for never using cotton were similar to those for stopping the use of cotton, but the ranking differs among the reasons (Table VII). Many of the firms have never used cotton to produce nonwoven products. Of these, 27% indicated that the 'products don't need cotton. (This response may also have encompassed the belief that the technology was not appropriate for use with cotton.) 'Higher production cost' was the second most frequent reason given (21.5%) for not using cotton.

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 fibres. These reasons were also similar to those firms currently using cotton and those who expect to increase cotton use. The response among the "non-cotton using" firms for willing to using cotton was 46%, if all technical constraints were removed.

[3] 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 VII. Responses from firms regarding reasons for different cotton use status

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%)	Production cost (21.5%)
Price advantage (16.7%)	Price Volatility (13.3%)	Change in demand (10.2%)
Reliable source (14.0%)	Introduction of new fibre (10.5%)	Others (8.8%)
Others (3.7%)	Difficulty in procurement (10.0%)	Price volatility of cotton (8.5%)
	Others (9.5%)	Difficulty in procurement (6.5%)

Note: Total percentage may not add to 100%, Weight average of the top 3 rank order choices was calculated. Weight average= (Rank1*3+rank2*2+Rank1*1)/6.

DISCUSSION AND CONCLUSION

The largest single category of nonwoven textiles is for personal care and hygiene products and its use increases with increased in demand for sanitation products. The short life cycles (many are single-use products) enable large production volumes and reliable revenue flows. Cotton fibres have excellent properties for serving most of these types of products and are compatible with some of the major technologies used to produce them. However, major three 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 fibres, so the technologies are generally more 'friendly' to these fibres. Furthermore, the manufactured fibres 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 fibre.

- 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: Polyester dominates in many nonwoven textiles and its prices have generally been lower and less volatile than cotton prices. The manufactured fibres can generally be produced on a continuous basis, while cotton production is subject to growing seasons and weather events that cause uncertain leads and lags in pricing behavior. Manufactured fibres can be offered at a fixed price going months into the future without requiring the trouble and expense of hedging for the risk of price changes. (Thus, even a higher price for these fibres 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.

The superior fibre 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 utilise cotton.

Nonwovens for which cotton clearly has demand-driven advantages versus substitute fibres are absorbent and hygienic products, medical/surgical and health care products, personal care products, and wipes. Cotton has the required fibre 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 factors constrain its use.

A major implication to take from this study is that technical feasibility of using cotton fibres in nonwoven textiles is currently insufficient to incentivise significant increases in the use of cotton. The aforementioned economic constraints must be alleviated. Thus, to have a meaningful impact, research should be aimed at modifying the marketing channels (e.g., forward contracting to stabilise prices over time), providing 'pure', prepared cotton fibres (e.g., incorporating pre-processed fibres into nonwoven marketing channels), or altering fibre properties (e.g., genetic engineering or developing cotton varieties specifically for nonwoven applications). Without breakthroughs in these arenas, cotton appears destined to remain a niche fibre in nonwoven textiles.

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