

Development and characterization of bamboo and organic cotton fibre blended baby diapers

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This paper reports study on the development and characterization of baby diapers made from four different fibrous compositions, namely pure bamboo, pure organic cotton, bamboo/organic cotton (70/30), and bamboo/organic cotton (50/50). Antibacterial activity tests have been carried out on baby diapers against *S aureus* and *E coli*. Superabsorbent polymer sodium polyacrylate has been incorporated into the diapers to enhance their absorption capacity. Various tests such as product density, thickness, absorption capacity, liquid strike-through, acquisition time under load and diaper rewet under load have been carried out to study the performance of the diapers. It is found that the diaper made from bamboo/organic cotton (70/30) exhibits best performance.

Keywords: Absorption capacity, Acquisition time, Bamboo, Diaper, *E.coli*, Liquid strike-through, Organic cotton, Superabsorbent polymer, *S.aureus*

1 Introduction

An important area of textiles is the healthcare and hygiene sector among other medical applications. The range of products includes both disposable and non-disposable items such as surgical gown, mask, surgical drapes, towels, gloves, baby diapers, sanitary napkins and so on used in hospitals¹. Bamboo fibre has excellent properties that make it ideal for processing into textiles. It has been found² that bamboo contains a unique antibacterial and bacteriostasis bio-agent named 'bamboo kun'. It is highly water absorbent, able to take up three times of its weight of water. The bamboo fibre has a natural effect of sterilization, moisture vapour transmission property and easy drying. Therefore, this fibre will not cause skin allergies and its application in sanitary materials such as baby diaper, absorbent pads and sanitary towels is found to increase³. Superabsorbent polymer (SAP) absorbs up to 200 times of its own weight of water, whereas the conventional wood-pulp and cotton-filler absorbents absorb only six times of their weight⁴. SAP granulates retain large quantities of liquid by forming a gel when in contact with it. SAP granulates are not used alone but are combined with

other materials to form a component capable of absorbing liquids. Disposable diapers are generally composed⁵ of a top sheet, SAP that forms the absorption part (fluff pulp+tissue+polymer), fastening tape and water proof film (back sheet). Superabsorbent disposable baby diapers are sophisticated, well-engineered products that provide many benefits including convenience, comfort, exceptional leakage protection, improved hygiene and skin care as compared to cloth diapers⁶. Baby diaper utilises cellulose fluff combined with superabsorbent polymer to create the absorbent core, which acts as the storage structure in the product. In some products, wet laid cellulose tissue may be used as containment wrap around the cellulose pulp^{7, 8}. As diapers come in contact with the skin, consumers are concerned about whether they cause dermatitis or not. Water transport properties such as absorption capacity and strike-through time are important as regard the wet comfort of diapers^{9,10}.

In the present work, an attempt has been made to produce baby diapers from bamboo fibres, organic cotton and their blends. It is expected that the incorporation of bamboo fibres will impart antibacterial property and enhance the absorbency of diapers. The performance of the baby pads, such as absorption capacity, liquid strike-through and diaper rewet under load has also been studied.

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2 Materials and Methods

2.1 Materials

Bamboo fibre and organic cotton were procured from Super Spinning Mills Ltd., Coimbatore. Other materials such as superabsorbent polymer, polypropylene based nonwoven, plastic sheet and adhesive were procured from the market.

2.2 Methods

2.2.1 Measurement of Bamboo and Organic Cotton Fibre Properties

The moisture content and regain of bamboo fibre was determined as per ISO 6741-1: 1989 method. The fineness of bamboo fibre was measured using BISFA 1988 method. The tenacity and elongation of bamboo fibre were determined as per ASTM D-3822-01 method. The properties of cotton and organic cotton fibres such as moisture content, fineness, tenacity and elongation were measured as per ASTM D-5867-05 method using high volume instrument (HVI).

2.2.2 Scouring of Organic Cotton Fibres

Scouring is the process of removal of natural and added impurities present in textile materials in order to improve the absorbency. The organic cotton fibres were scoured using caustic soda and other auxiliaries as per the standard procedure.

2.2.3 Evaluation of Antibacterial Activity of Fibres

Pure bamboo and pure organic cotton fibres were tested for antimicrobial activity using ASTM E-2149 method, which is a quantitative antimicrobial test method performed under dynamic contact conditions. *E.coli* and *S.aureus* were used as test organisms. The incubated test culture in a nutrient broth was diluted with a sterilized 0.3mM phosphate buffer (pH 7.2) to give a final concentration of $1.5-3.0 \times 10^5$ colony forming unit (CFU/ml). This solution was used as a working bacterial dilution. The antimicrobial activity was expressed in terms of reduction in the organism after contact with the test specimen as compared to the number of bacterial cells surviving after contact with the control. The reduction was calculated using the following equation:

$$\text{Reduction (\%)} = \frac{B-A}{B} \times 100$$

where A and B are the surviving cells (CFU/ml) for the flask containing test samples and the control (blank sample) respectively after a contact time of 1 h.

2.2.4 Determination of Absorbency of SAP

The absorbency of superabsorbent polymer (SAP) was determined using the procedure given in US patent (5,419,955). The nylon cloth was cut into 6 cm × 12 cm strips. Accurately weighed (W_1) 1.0 g of the superabsorbent polymer (SAP) was taken in the nylon bag. Five such nylon bags were prepared and sealed. Two empty nylon bags (blank samples) were also prepared. Then 0.9% saline solution is filled in the plastic container upto 1.5 inch in depth. The nylon bag with SAP was held horizontally and SAP was distributed uniformly throughout the bag. The bags with SAP and without SAP were laid on the surface of the saline and allowed to wet for 1 min before it is submerged. After a soaking period of 60 min, the bag was removed and allowed to drip for 15 min. The average weight (W_3) of five nylon bags containing SAP was determined. The blanks were also weighed (W_2) and the total absorbency was calculated using the equation given below:

$$\text{Total absorbency (g/g)} = \frac{[(W_3 - W_2) - W_1]}{W_1}$$

where W_1 is the initial weight of the SAP; W_2 , the average weight of blank samples after the test; and W_3 , the weight of bag with SAP after the test.

2.2.5 Preparation of Baby Diapers

Baby diapers were prepared from four different fibrous compositions namely pure bamboo, pure organic cotton, bamboo/organic cotton (70/30), bamboo/organic cotton (50/50). The fibres were opened and blended using Shirley opener. The bottom sheet was made by a polypropylene film, which is nonporous and hydrophobic substance that helps the baby's clothing to remain dry. Superabsorbent polymer of about 5 g was sprinkled over the bottom layer of diaper. About 12 g of fibre (weighed accurately) was compressed and placed between the top two sheets of 15 cm × 35 cm polypropylene nonwoven and a bottom sheet of the same size. The top sheet allows the urine to flow through it but does not allow the liquid to remain near the baby's skin. After placing it accordingly, all the sides of the diaper were sealed by applying heat and the edges was sealed with an adhesive (Fevikwik).

2.2.6 Performance Testing of Baby Diapers

2.2.6.1 Liquid Strike-through Test

A drop of test solution was allowed to fall on the sample and the time taken for the solution to transport

from the upper layer of the diaper to the inner layer was noted. The measurement was done by closely observing the drop, such that a dull wet spot is seen on the wet area of the sample, as suggested earlier¹⁰.

2.2.6.2 Absorption Capacity

The primary purpose of disposable diapers is to absorb the urine, dispersing it quickly and to retain the absorbed fluid without re-wetting of the surface. The total absorptive capacity of the diaper was determined using EDANA method. It was assessed by immersing the product into a known test solution for a standard time and measuring the difference in weight.

2.2.6.3 Acquisition Time and Rewet under Load

Acquisition time and the rewet under load for disposable baby diapers are critical. It is the time required for the diaper to fully absorb a known amount of test fluid under load. The load is applied to simulate the baby weight. In addition, re-wetting of diaper is also measured. It shows the ability of the diaper pad to rewet the surface under the application of a simulated load (approx. 2.5 kg)¹¹.

2.2.6.4 Product Density and Thickness

Each diaper pad was conditioned for 24 h at 24°C and their weights were measured using a weighing balance which has an accuracy of 0.001 g. The thickness measurements were carried out at three distinct places of the diaper pad, on both sides and at the middle, which were marked as S, M and L¹¹.

3 Results and Discussion

3.1 Properties of Bamboo Fibres and Organic Cotton

The properties of bamboo and organic cotton fibres are given in Table 1. It can be observed that the moisture content and regain of bamboo fibre is 12.7% and 14.5% respectively. It is almost double as that of organic cotton fibre. This property enhances the absorbency of fluid very rapidly. Further, the bamboo fibres have similar tenacity but are highly extensible as compared to both cotton and organic cotton. In addition, the bamboo fibre is exceptionally soft, light, silky and its cross-section is filled with several micro-gaps and micro-holes which makes it breathable and cool to wear. It has natural functions of antibacterial, anti-ultraviolet, sterilization, bacteriostatis and deodorization¹². Therefore, bamboo fibre products do not cause skin allergies and protect the children from ultraviolet radiation.

3.2 Antibacterial Activity of Fibres

The antibacterial properties are very important for underwear garments because many harmful bacteria

Table 1 — Properties of bamboo, organic cotton and cotton fibres

Property	Bamboo fibre	Organic cotton fibre	Cotton fibre
Moisture content, %	12.7	6.7	6.8
Moisture regain, %	14.5	7.2	7.3
Fineness, dtex	1.8	1.5	1.5
Tenacity, cN/tex	22.5	22.8	26.3
Elongation, %	20.5	5.7	8.6

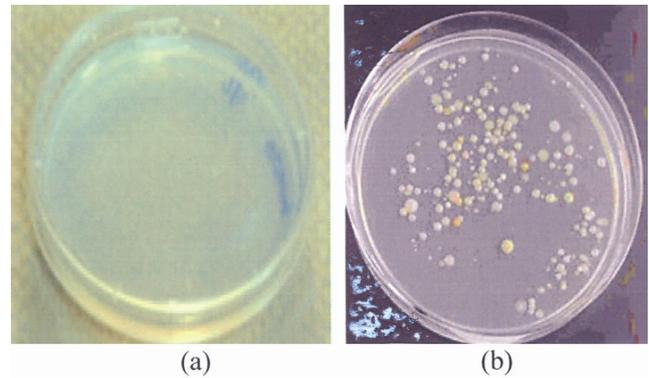


Fig. 1—*S.aureus* bacterial reduction (a) pure bamboo and (b) pure organic cotton

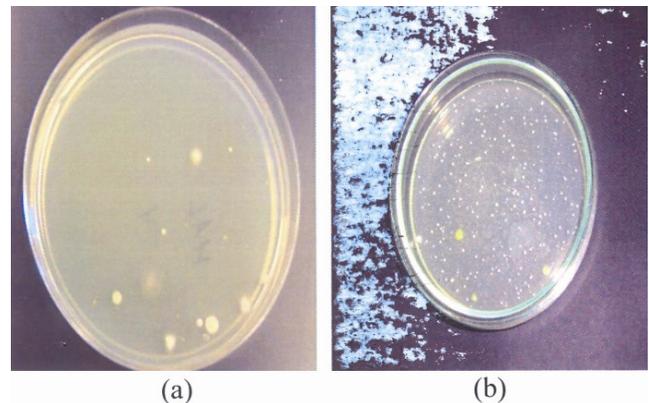


Fig. 2—*E.coli* bacterial reduction (a) pure bamboo and (b) pure organic cotton

reside between apparel and human skin. The antibacterial activity of pure bamboo and pure organic cotton fibres is depicted in Figs 1 and 2. It is found that the pure bamboo fibre shows 100% and 98.75% reduction against *E.coli* and *S.aureus* bacteria respectively. However, the organic cotton fibre shows zero reduction in case of the two bacteria respectively. Bamboo fibres are efficacious against *Bacillus*, *Candida albicans*, *Staphylococcus aureus* and *Escherichia coli*. Scientists have found that bamboo contains a unique antibacterial and bacteriostasis bio-agent named 'Bamboo Kun'. This substance imparts the natural functions of antibacterial activity and

deodorization¹². This clearly demonstrates the antibacterial activities of bamboo fibre which enhances the comfort of the wearer. Its natural antibiosis function keeps bacteria away and hence it does not produce bad odour. They are extensively effective in antibacterial activity.

3.3 Total Absorbency of Superabsorbent Polymer

Superabsorbent polymers are the materials that have the ability to absorb and retain liquid (~70-200 times of their weight) under a slight mechanical pressure (1-5 kPa in diapers). The swollen gel holds the liquid in a solid, rubbery state and prevents the liquid from leaking onto the baby's skin and clothing, which helps the baby to stay dry for a long duration. It is found that the total absorbency of superabsorbent polymer (sodium polyacrylate) is 107 times of its own weight. This plays a vital role in the performance of a diaper. Superabsorbent polymers are cross-linked networks of flexible polymer chains. The polymer used in diapers is a high molecular weight sodium polyacrylate polymer. Similar SAPs have been used safely for years in sanitary napkins and adult incontinence products. Scientific safety testing and a long market history on these materials support the conclusion that they are non-irritating, non-allergenic, and safe for consumers¹³.

3.4 Performance of Baby Diapers

3.4.1 Liquid Strike-through Test

In the case of liquid strike-through, the diapers composed of bamboo/organic cotton blends of 70/30 and 50/50 proportions take 1.13s and 0.93s respectively to transport the liquid from their surface, whereas the diaper made of pure organic cotton takes less time 0.75s. The pure bamboo diapers take more time 1.44s to transport the liquid from their surface due to the poor wicking property of the fibre. Thus, the diapers composed of bamboo/organic cotton blends of both 70/30 and 50/50 proportions readily take-up the fluids and keep the skin dry, avoiding wetness. The water transport properties of diapers are considered to be related to both diaper dermatitis and wearing comfort. The 0.01s level of accuracy was maintained in the test.

3.4.2 Absorption Capacity

All the baby diaper pads were assessed for their absorption capacity. The results indicate that the diapers composed of bamboo/organic cotton (70/30) and pure bamboo have high absorption capacity than the diapers made of pure organic cotton and

Table 2 — Performance of baby diapers

Parameter	Baby diaper			
	Pure bamboo	Pure organic cotton	Bamboo/organic cotton (70/30)	Bamboo/organic cotton (50/50)
Average size, cm ²	15×35	15×35	15×35	15×35
Average product thickness, mm	6.92	8.37	10.55	9.51
Average weight, g	18.84	19.19	20.07	20.03
Absorption capacity, g/g	11.34	11.16	11.40	11.15
Liquid strike-through, s	1.44	0.75	1.13	0.93
Acquisition time under load, min	1.24	1.19	1.18	1.19
Diaper rewet under load, g	5.88	6.34	1.83	2.46

bamboo/organic cotton (50/50) blend. However, these pads possess similar absorption capacity. In general, the best wet comfort is provided by pads with high absorption capacity, low rewet and fast strike-through.

3.4.3 Acquisition Time and Rewet under Load

The samples were also evaluated for acquisition time and rewet under a simulated load. The test result shows that the diapers composed of bamboo/organic cotton (70/30), pure organic cotton and bamboo/organic cotton (50/50) take less time to transport the known liquid from their surface than the diapers made of pure bamboo. In addition, the diaper made of bamboo/organic cotton (70/30) shows lesser rewet value as compared to all other diaper pads. The diaper made of pure organic cotton possesses high rewet value (6.3 g) followed by the pure bamboo diaper (5.8 g) and bamboo/organic cotton (50/50) blend diaper (2.4 g). The lesser the rewet value the better is the performance of the diaper. If the absorbed fluid surfaces on to the diaper, then it would cause dampness and would result in skin infection.

3.4.4 Product Density and Thickness

It is observed that the diaper made of pure bamboo is lighter as compared to all other products, while the baby pads composed of bamboo/organic cotton (70/30) and bamboo/organic cotton (50/50) are heavier products comparatively. In addition, taking the bulkiness into account the pads made of bamboo/organic cotton (70/30) and bamboo/organic cotton (50/50) are thicker. Pure bamboo diaper is the thinnest product (6.9 mm) followed by pure organic cotton pad (8.3 mm). The results of product density and thickness, liquid strike-through, absorption capacity, acquisition time under load and rewet under

load are given in Table 2. In general, the best wet comfort is provided by the pads with high absorption capacity, low rewet and fast strike-through time.

4 Conclusions

4.1 Liquid strike-through time is lowest for the baby diapers composed of pure cotton, bamboo/organic cotton blends of both 70/30 and 50/50 proportions, while highest for the one made of pure bamboo fibres.

4.2 Absorption capacity is highest for the diapers made of bamboo/organic cotton (70/30) and pure bamboo.

4.3 Acquisition time under load is lowest for the diapers composed of both 70/30 and 50/50 proportions of bamboo/organic cotton blends. It is highest for pad made of pure bamboo.

4.4 The rewet under load is lesser for the diaper produced from bamboo/organic cotton (70/30).

4.5 The diaper pad composed of pure bamboo fibre is lighter as compared to all other products.

4.6 The baby diapers made of both 70/30 and 50/50 blends of bamboo/organic cotton perform well with regard to absorption capacity, liquid strike-through, low rewet value and medium weight. Hence, these baby diapers are found to be the best.

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