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Hygiene pads from natural fiber: A feasibility study on two Indian bamboos

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Abstract: At present, hygiene pads (sanitary napkins and incontinence pads) are produced from wood cellulose and synthetic absorbent polymers (non-biodegradable). A feasibility study utilizing fibers of two Indian bamboo species. *Oxytenanthera stocksii* and *Bambusa bambos* for making hygiene pads was undertaken. Digestion studies on bamboo chips as well as bamboo cuttings originate during manufacturing of bamboo mats were carried out at two different temperatures and pressures to obtain the fibers of desired performance, and process was optimized for both the species. Due to higher lignin content in bamboo, the steps of bleaching were optimized to obtain brightness of up to 75 per cent to meet the requirement of aesthetic appeal of hygiene pads. The study has demonstrated that the properties like absorbency, water retention and rewet behaviour essential for the hygiene pads can be achieved using bamboo fibers which are comparable to those of hygiene pads based on wood pulp.

Key words: *Oxytenanthera stocksii*, *Bambusa bambos*, hygiene pads, digestion, absorbency.

INTRODUCTION

Hygiene pads are as essential as any health care product mainly because of the fact that they ensure personal hygiene, proper conditions of sanitation, and provide assurance about the state of overall well being. Hygiene pads are made up of three layers: 1) inner layer (in contact with the body skin), 2) middle layer (also called absorbent layer capable of absorbing and holding body fluids), and 3) outer layer (non–porous layer to prevent the leakage of fluids absorbed by middle layer). All the three layers have a role to play in the overall performance of the pads, but the absorbent layer obviously plays an important role and hence, the development of suitable material for the absorbent layer has always been the focus of research world over.

The absorbent layer is generally designed using the materials having the essential properties like: 1) absorption of body fluid, 2) retention of the absorbed fluid, 3)

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rewet behavior, which indirectly means that the fluid does not ooze out of the layer even under pressure, 4) stable constitution of absorbent layer structure which prevents bunching while the product is in use and, 5) desired physico-mechanical strength (Bhatt *et al.*, 2003). Considering the requirements, options available as the suitable material for the absorbent layer are given in Table 1, along with the associated features and disadvantages for each option.

Conventionally, wood pulp is used in hygiene pads along with or without super absorbent polymers (SAP) (Dhamodharan *et al.*, 2003; Fengel and Wegener, 1984). Generally, the processing of wood to obtain the wood pulp involves the separation of lignin content from the desired ingredient (alpha cellulose) of the wood pulp. The two basic types of wood *i.e.*, hard wood and soft wood behave differently during the processing mainly due to the problems associated with removal of lignin from them; soft wood with lower lignin content behaves much better than the hard wood. The problems related to the availability of the wood and the cost of technology for converting the wood into sorbing material necessitate to explore alternative renewable resources that can be used for this purpose. Bamboo could be one such candidate.

Anatomically bamboo is similar to hard wood, as it contains vessel elements *i.e.*, xylem and phloem. Contrary to this, soft wood contains only two types of cells, longitudinal fibres (tracheids) and transverse ray cells. Further, solid pith is present both in hardwood and softwood stem from top to bottom. As compared to this most bamboo species contained solid pith only in nodal region and internodes are devoid of pith and it usually remains as hollow. Alpha cellulose content in different bamboo species ranges from 40-50 per cent, which is comparable to the reported alpha cellulose content of soft wood (40-52%) and in hard wood (38-56%). Cellulose content in this range makes bamboo a suitable alternative raw material for hygiene pads. So far, bamboo has not been explored for personal hygiene products. In the present study, performance of *Bambusa bambos* and *Oxytenanthera stocksii,* commonly found bamboo in Konkan (Maharashtra) and Karanatka regions in India, for exploiting in hygiene products was evaluated.

EXPERIMENTAL

Materials

B. bambos and *O. stocksii* selected for the study were procured from the Konkan region of Maharastra. Chemicals used for the purpose of digestion and bleaching are: sodium hydroxide, sodium sulphide, bleaching powder, sodium chlorite, hydrochloric acid, formic acid, all are commercial grade, procured from the local market of Delhi. Digester (100 l), Hydroextarctor (12 kg), Oven for drying pulp, opening and compression moulding machine, *etc.,* were used.

Methods

Process flow diagram showing steps involved in manufacturing of absorbent layer for hygiene pads from bamboo is given in Figure 1. The details of digestion and bleaching steps of process are given below:

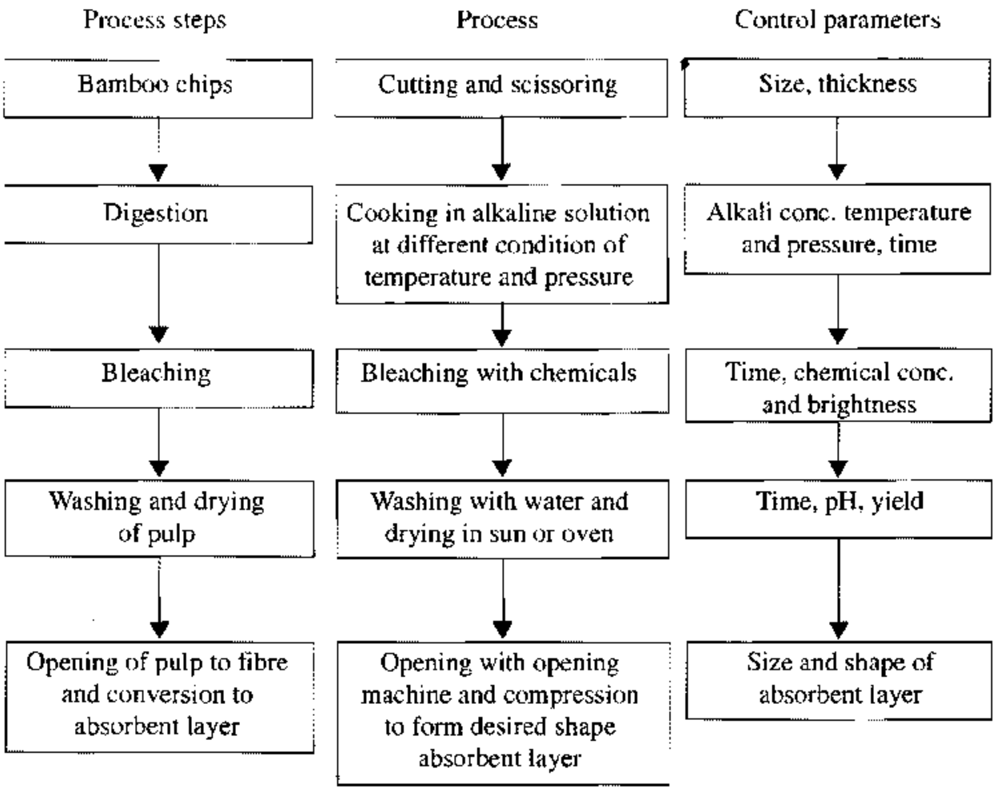

Figure 1. Flow diagram showing various steps involved in process of conversion of bamboo to absorbent layer to be used in hygiene pads.

Digestion

The digestion studies were carried out on a semi-pilot scale. Two different types of materials, bamboo chips of thickness 2-3 mm and bamboo cuttings as waste from the handicraft industry were used. For the digestion, 15 kg of material was charged in a 100 l capacity electrical heated, SS 304 digester. Digestion was carried out for a period of 1 h at two different conditions of temperature and pressure: 160° C at 7.5 kg/cm^2 and 170° C at 9.5 kg/cm^2. Digestion studies on cutting waste of *O. stocksii* were carried out using only 10 kg of material, instead of 15 kg of chips due the fact that bulk density of the cutting waste is much lower than that of the chips. After digestion, the pulp was analysed for lignin content using the TAPPI method T-222.

Bleaching

As against conventional method for bleaching which involves 6 to 7 stages of bleaching to get a brightness of 90 to 95 per cent, which also includes the handling of chemicals such as chlorine gas, hydrogen peroxide, sulphur dioxide, *etc.*, two steps bleaching process was developed in the present study to obtain the white bamboo pulp. These include: first, with bleaching powder in water, and then with the solution of sodium chlorite and formic acid in water to bleach in hot water (90° C). The bleached pulp was washed and squeezed using hydroextractor and then dried using oven. The bleaching process was monitored by checking the brightness of the fibre by gloss reflectance meter. After bleaching, pulp of both the bamboo species was characterised for alpha cellulose content using the method as per IS: 1060 (Part 11) 1960.

Absorbency, water retention and rewet test

Pulps obtained after bleaching was molded into shape of absorbent layer and tested for absorbency (IS-2369), water retention (ASTM- D 2402), and rewet properties (ISO 11948-2:1998(E). Materials uesd for absobent layer with characteristic features are given in Table 1.

Table 1. Options available for absorbent layer with characteristic features and disadvantages

Sl.No.	Options of materials for absorbent layer	Features	Disadvantages
1.	Wood fibre	Good absorbency and retention due to short fibre length of 0.7-0.8 mm	Deforestation, short life cycle
2.	Fibre from grasses like sugarcane, rice, *etc.*	Good absorbency and retention fibre length of 1.5-1.7mm	Consumed as food and fibre used in boilers, limited availability.
3.	Synthetic absorbent polymers (SAP)	Very high absorbency and retention	Non-biodegradable create environmental pollution

RESULTS AND DISCUSSION

Digestion

The yield of bamboo pulp under different digestion conditions varies from 38 per cent to 41.5 per cent (Table 2). Optimum results were obtained at temperature 160°C and pressure of 7.5 kg/cm^2. At higher temperature and pressure, the yield showed a decline of 10 per cent. This is mainly due to the degradation of the fibre. In *O. stocksii* the yield was found lower for cutting than the chips mainly because of the fact that cutting waste was consisting of a significant quantity of undigestible material. In the case of *B. bambos* similar effect of increase in temperature and pressure was observed on per cent yield.

Table 2. Process data for digestion of two species of bamboo at two different temperatures and pressures

Expt. No.	Bamboo specifications	Weight of bamboo material (kg)	Alkali mixture $NaOH + Na_2S$ (%)	Cooking temp. for 1 h (°C)	Pressure (kg /cm²)	yield (%)
Digestion of *Oxytenanthera stocksii*						
1.	Chips of 2-3 mm thickness	15	20	160	7.5	41.5
2.	Chips of 2-3 mm thickness	15	20	170	9.5	38.5
3.	Cutting waste	10	20	160	7.5	40.5
4.	Cutting waste	10	20	170	9.5	38.5
Digestion of *Bambusa bambos*						
1.	Chips of 2-3 mm thickness	15	20	160	7.5	40
2.	Chips of 2-3 mm thickness	15	20	170	9.5	38

Lignin and alpha cellulose content

The results of lignin content before and after digestion are given in Table 3. The lignin content in *O. stocksii* and *B. bambos* before digestion was 28.5 per cent and 25.6 per cent respectively. The higher content of lignin in *O. stocksii* is responsible for more hardness than *B. bambos*. On digestion at 160°C and 7.5 kg/cm² pressure, the lignin content in *O. stocksii* is reduced from 28.5 per cent to 7.5 per cent. When the digestion is carried out at higher temperature and pressure (170°C and 9.5 kg/cm²), the lignin content further reduced to 5.8 per cent. The result of lignin content in *B. bambos* after digestion also showed similar trend with *O. stocksii* (Table 3). Generally, the efficiency of the digestion process is checked based on the two main control parameters, *i.e.*, alpha cellulose content and lignin content. From the results, it is quite evident that by raising temperature and pressure one can bring the lignin content down, but then there is a risk of damaging the cellulose fiber which is responsible for the absorbency. The results of alpha cellulose content after digestion and bleaching showed that the values are within the acceptable range (>85 %), required for hygiene pads. The alpha cellulose content in *O. stocksii* at 160°C temperature and

Table 3. Lignin and alpha cellulose after digestion at two different temperatures

Bamboo species	% Lignin (before digestion)	% Lignin at 160°C after digestion	% Lignin at 170°C after digestion	Alpha cellulose in bleached pulp obtained after digestion at 160°C	Alpha cellulose in bleached pulp obtained after digestion at 170°C
B. bambos	25.6*	6.6*	4.6*	88.5%*	90 %*
O. stocksii	28.5*	7.5*	5.8*	87.5 %*	88.2%*

*Average of results obtained for 3 samples in each case.

7.5 kg/cm^2 pressure was 87.5 per cent, whereas at 170°C temperature and 9.5 kg/cm^2 pressure it was 88.2 per cent. In the case of *B. bambos*, the alpha cellulose content at 160°C and 7.5 kg/cm^2 pressure was 88.5 per cent, whereas at 170°C and 9.5 kg/cm^2 pressure it was 90 per cent. From the results following inference can be made:

(a) The optimum temperature and pressure for digestion for both the species of bamboo is 160°C and 7.5 kg/cm^2. This not only results in better yield but also provides the good quality fibre without any damage.
(b) *B. bambos* is good raw material which behaves relatively better than *O. stocksii* on digestion.

Bleaching studies

The maximum brightness ~ 75 per cent for *B. bambos* and 74 per cent for *O. stocksii* was obtained for the samples digested at 170°C and 9.5 kg/cm^2. For the samples digested at 160°C and 7.5 kg/cm^2 the brightness was 72 per cent for *B. bambos* and 70 per cent for *O. stocksii* (Table 4). The samples of cutting waste of *O. stocksii* showed

Table 4. Data showing bleaching of digested pulp with per cent brightness

S. No.	Digested pulp obtained from	Bleaching with 50 per cent bleaching powder		Bleaching with 75 per cent bleaching powder	
		Bleaching with 0.5 % sodium chlorite % Brightness of white color	Bleaching with 1% sodium chlorite % Brightness of white color	Bleaching with 0.5% sodium chlorite % Brightness of white color	Bleaching with 1% sodium chlorite % Brightness of white color
1	*O. stocksii* (chips of 2-3 mm thickness) digested at 160°C	64	63	67	70
2	*O. stocksii* (chips of 2-3 mm thickness) digested at 170°C	63	65	69	74
3	*O. stocksii* (cutting waste) digested at 160°C	51	54	49	51
4	*O. stocksii* (cutting waste) digested at 170°C	46	48	48	50
5	*B. bambos* (chips of 2-3 mm thickness) digested at 160°C	62	65	67	72
6	*B. bambos* (chips of 2-3 mm thickness) digested at 170°C	63	65	65	75

a much inferior brightness (~50 %) compared to that of chips. In all the cases brightness is significantly lower than the desired limit *i.e.,* 90 per cent (Table 4).

Absorbency, water retention and rewet test

Absorbency of fibre obtained after digestion and bleaching of both bamboo species was found to be 4-5 sec comparable with market available hygiene pads (Table 5). Water retention of fibre obtained from both species after digestion and bleaching was found to be 120 per cent comparable with market available hygiene pads (Table 5). The load required to rewet the hygeine pad made from bamboo fibre was found 800 g comparable to the load required to rewet the market available wood fiber based hygiene pads (Table 5).

Table 5. Comparison between absorbency, water retention and rewet of market available products and bamboo based hygiene pads

Market sample	Absorbent core	Absorbency (Sec) by IS 2369	Water retention (%) by ASTM D 2402	Rewet (Load in g)
A	Wood cellulose fiber	4-5	115-120	750
B	Wood cellulose fiber	5-6	110-115	800
C	Wood cellulose + tissue paper	10-11	115-120	750
Bamboo based hygiene pad	Bamboo cellulose fiber	4-5	115-120	800

CONCLUSIONS

Bamboo chips and cutting waste can be converted into bamboo fibre for use in hygiene pads.Hygiene pads made up of bamboo fiber match the essential features and properties of the hygiene pads available in the market. Further, this study provides the following basic inputs that can be used for commercial exploitation with value addition of the bamboo:

(1) Digestion of bamboo pieces (chips as well as cuttings) could be done better at 160°C and 7.5 kg/cm^2 pressure.
(2) Bleaching can also be carried out in two steps rather than multi—steps bleaching being adopted for such products.
(3) An optimum content of alpha cellulose with minimum amount of lignin can be achieved using the process of digestion and bleaching.
(4) The basic features and properties essential for the absorbent layer of hygiene pads can be achieved with the processed bamboo.

Based on this work, the authors have already put two manufacturing facilities as the demonstration units at Maharastra and Nagaland.

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