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Matchsticks from bamboo

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Abstract—The match Industry has been dependent on few wood species for making match splints that are now in short supply. Development of matchsticks from bamboo acquires special significance due to the fact that, apart from being available in natural forests, bamboos can be grown on a very short rotation of 2–3 years in various parts of the country.

Bamboos have several intrinsic characteristics that have prohibited their use for making matchsticks, including poor penetration of wax that is required to produce good incandescence and burning quality. To evolve suitable processes and parameters for making quality match splints from two widely occurring species of bamboo in Southern India, namely *Bambusa bambos* and *Dendrocalamus strictus*, extensive experiments were conducted at IPIRTI under a project funded by the International Network on Bamboo and Rattan.

At present, the match industry is using 2 mm thick wooden splints for manufacturing matchsticks. However, bamboo match splints of 1.5 mm squared were found to pass the test of strength prescribed in the relevant Indian Standard specification for match splints. Treatment with hydrogen peroxide was necessary to improve the physical appearance of the bamboo match splints, followed by dipping in boric acid, or boric acid and borax mixture at 0.5–1.0 ratio to improve after-glow property. Waxing through dipping in molten wax at 100–120°C for 8–12 s facilitated satisfactory transfer of flame from the matchstick head and burning properties. Due to smaller size, the box size required for packaging 50 splints will be smaller resulting in significant saving of wood/paper for making matchboxes. A joint Indian patent has been filed by IPIRTI and INBAR in Chennai Patent Office (MAS/627/2000 dated 07.08.2000)

Limited trials in a factory at Sivakasi–Tamilnadu were carried out, especially on waxing and head fixing, and the results were found to be very encouraging.

Key words: Matchsticks; bleaching; carbonisation; wax fixation; fire retardant chemicals.

1. INTRODUCTION

The use of wood for burning is as old as fire itself. The development of matches has been an important technological advancement facilitating burning wood or other

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materials for various purposes. The match industry combines one of the basic uses of wood with vital needs of man for fire. The most important raw material for the match industry has been wood for splints. Since the 1920s India has imported aspen logs for making match splints, as the required quantity of aspen (*Populus tremula* Linn) wood is not available in the forests. Alternative species such as semul (*Bombax ceiba*), rubber (*Hevea braziliensis*) and matti (*Ailanthus malabaricum*) have been found suitable for the match industry. In recent times, there has been a considerable depletion in supply of matchwood due to the fact that many of these tree species have found alternative and more profitable applications in wood-based panel industry. In spite of development of different types of lighters, safety matches continue to be an essential consumer commodity needed by all sections of society.

The demand for matches is increasing with increasing population. There have been several assessments of the demand for matchwood in India, the latest being as a part of demand assessment for all wood-based industries [1] 1000 gross boxes of 50s require about 5 m^3 of wood for match splints and about 2.5 m^3 of wood for matchboxes. Based on reported production, the total requirement of wood was estimated to be 2.3 million cubic meters in 2000 and 4 million cubic meters in 2020 (Table 1). The availability of matchwood presently is only to an extent of 0.5 million cubic meters. The short supply of wood is a serious problem for the match industry in this country.

A survey of fast growing woody plants focused IPIRTI's attention on a very fast growing woody grass, 'bamboo'. India is one of the leading countries in the world bamboo production with 125 species belonging to 23 genera found in various parts the country. They form an important associate of deciduous and evergreen forests covering both tropical and temperate zones. They grow very well in alluvial plains having good moisture regime and up to 3000 m in high mountains. Important genera that are found in India include *Bambusa tulda, Bambusa vulgaris, Dendrocalamus hamiltonii, Dendrocalamus strictus, Melocanna bambusoides, Gigantochloa spp., Ochlandra travancorica* and *Oxytenathera nigrociliata*. Unlike woods raised for production of matchsticks that require growing periods of 10 years or more, utilizable bamboo of species can be grown within 2–3 years. Many species of

Table 1.
Demand for wood by Indian match industry

Year	Demand (round wood equivalent) million m^3
1998	2.1
1999	2.2
2000	2.3
2005	2.6
2010	3.0
2015	3.4
2020	4.0

bamboo are known to grow several centimetres in height daily during the growing season [2, 3].

2. INDIAN MATCH INDUSTRY

The first match industry in India was established in the 1920s, prior to which the entire demand of matchsticks was met by imports from Sweden and Japan. Since then, several industries have arisen in different states. Mechanized match industries are located in the states of Maharashtra, Tamil Nadu, Uttara Pradesh, West Bengal and Assam. Several non-mechanized factories are situated in Tamil Nadu. Wood used by these industries are from Semul (*Bombax ceiba*), machilus (*Machilus macrantha*), mango (*Mangifera indica*) and Dhup (*Canarium sp.*). The factories located in Tamil Nadu use mainly timber available from the forest of Kerala and Karnataka whereas factories located in Maharashtra use timber from the forests of Madhya Pradesh, and the West Bengal units use timber grown in the forests of Andaman Nicobar, Bihar, and Orissa. Similarly, the match factories in Uttar Pradesh get supplies from the forests of Uttar Pradesh, and the factory at Dhubri (Assam) gets supplies from forests of Assam, Bhutan and Arunachal Pradesh [4].

As supply of traditional match wood species is decreasing, a few alternative species have been evaluated, including bamboo. The history of utilizing bamboo for making matchsticks can be traced back to the pre-independence period in West Bengal. However, the process was not commercialised.

3. MATERIALS AND METHODS

In the experiments, two species of bamboo available in South India, namely *Bambusa bamboos* and *Dendrocalamus strictus* were used.

3.1. Strength of match splints

An important requirement of woody material for making match splints is that it should be light-weight, easy to be converted to very small cross-section (1.5–2 mm squared) and still strong enough to be mechanically charged for waxing and head fixing as specified in the relevant Indian Standard Specification [5]. The required size (cross-section) of bamboo splints was analysed so as to meet the strength requirement prescribed in the Indian Standard Specification [5]. Strength of the match splints was determined by giving an impact at the centre of the splints by a steel ball. A steel ball weighing 3.5 g was dropped from a height of 180 mm on the splint positioned on a v-shaped anvil. Bamboo splints were therefore tested against this standard using an apparatus fabricated at IPIRTI. The splints were made out of matured bamboo. Splints were air dried up to equilibrium moisture content. Length was kept at 32 mm (min) and cross-section 1.5 mm squared. The cross section was kept lower than the prevailing cross-section for wooden match splints assuming that bamboo has better strength compared to the wood species presently in use for making match splints.

3.2. Bleaching

Since the first matches used in India came from Sweden and were of aspen wood (*Populus tremula* Linn), and since the colour of this wood is natural creamy white, consumer preference has always been for light coloured match splints. Although it is not a technical requirement, it is almost a requirement for market acceptability of any new material for match splints. Bleaching is the process of removing the natural colouring matter from a material to make it light coloured. Bleaching agents can be reducing or oxidising, we used the later. Hydrogen peroxide having 30% concentration was diluted with water in the ratio of 1 : 1 to 1 : 2. To this, ammonia with a specific gravity of 0.45 was added, and bamboo splints were dipped in the solution for bleaching. The quantity of ammonia added was regulated to keep pH in the range of 8.0 to 9.0. Various concentrations of hydrogen peroxide and other chemicals, temperature and contact time were studied to find out the best combination for bleaching bamboo splints. After the required degree of bleaching the splints were washed with water 2 to 3 times.

3.3. Carbonisation

An important aspect of burning a matchstick is extinguishing the flame within a short time. This is achieved through cooling of the solid fuel and eliminating air from the combustion zone in the process of blowing out the burning matchstick. However, the lingo-cellulosic materials have a tendency to keep on simmering for prolonged periods after the flame is put out, called 'after-glow'. For safety matches, the shorter the period of after-glow the better it is. The period of after-glow in safety matches is reduced by carbonisation, a process in which the splints are treated with fire retardant chemicals. The simple act of blowing out a matchstick involves cooling the substrate and increasing the volume of air in the combustion zone. Fire retardant chemicals operate both in the solid phase (altering the thermal degradation process or forming barriers at the surface) and in the vapour space (interfering with oxidation). Wooden match splints are carbonised through treatment with selected chemical for 10 min, followed by drying. A similar method was adopted for bamboo for which an appropriate carbonising formulation was evolved.

Although most fire retardant chemicals centre around six elements, namely, phosphorus, arsenic, chlorine, bromine, boron and nitrogen, and there are occasional references to other elements such as bismuth, lead and zinc salts, it has been found that use of phosphorus or boron compounds accelerate the carbonised layer on cellulose based materials and give them the desired fire resistance [6]. Hence, fire retardant treatment was studied by using three boron and phosphorus compounds, namely, (i) boric acid, (ii) boric acid–borax, and (iii) phosphoric acid in concentrations varying from 0.25% to 2.0%.

3.4. Wax fixation

One important property expected from matchsticks is that the splints should catch the flame from the match head and give a proper flame height, when ignited. The splint should also hold the burning head composition firmly. Wax fixation to wooden splints are generally done by bringing into contact molten wax for about 2 s and heating the wax tipped splints for around 2–3 s on a hot plate to promote wax movement. As wooden splints have more porosity, wax moves into the pores within 4–5 s imparting good burning characteristics.

The structure of bamboo does not allow the wax to penetrate easily. For good wax penetration, the following measures were tried:

(1) Elevating the temperature of molten wax.

(2) Increasing the contact time of the splints with molten wax.

(3) Waxing splints that have attained equilibrium moisture content.

(4) Incorporating some chemical during bleaching to help increase penetration of wax by creating voids in bamboo splints.

As facilities were not available in the IPIRTI laboratory, head fixing was done in a factory at Sivakasi. It is the head composition that plays a key role in making a match splint ignite effectively when stroked against the coated surface provided in the matchbox. The temperature of the flame attained and transmission of heat to the splint are important in determining the quality of flame.

4. RESULTS AND DISCUSSION

The match splints have to be clean and smooth, straight and without bristles. Keeping this in view the second layer (inside the epidermal layer) was found to be suitable for making match splints.

The test specified for strength of match splints specifies that, under impact, splints should not crack or break. Maximum permissible proportion of splints with crack or break is 5% by weight. The test results performed on 1.5 mm to 2 mm splints made from the two species of bamboo are given in Table 2 which clearly reveals that match splints made from both the bamboo species meet the strength requirement as prescribed in the specification.

One of the most important parameters of the bleaching process is the pH of the treating solution. If the pH increases, the colour of the splints changes to yellow and if the pH decreases, it takes a longer time for bleaching, which may affect the strength of bamboo splints due to the acidity of hydrogen peroxide. Results of bleaching are given in Table 3 from which it may be seen that pre-treatment of splints either with sodium meta-silicate (0.5%) or with sodium hydroxide gave

Table 2.
Test of strength of bamboo match splints

Species	Type of splints	Thickness	Average pass of 8 samples	Range	Overall pass percentage
Bambusa	Machine made	1.5 mm	23	22–24	90.4
		2.0 mm	22	23–24	91.2
bambos	Manually made	1.5 mm	22	22–23	90.0
		2.0 mm	22	21–24	94.0
Dendrocalamus	Machine made	1.5 mm	23	22–24	90.4
		2.0 mm	23	21–24	90.4
strictus	Manually made	1.5 mm	24	23–25	99.0
		2.0 mm	23	21–24	89.8

1 unit = 25 splints, Total number of units = 80, Total number of splints tested = 2000 nos.

Table 3.
Effect of bleaching chemicals on appearance of bamboo match splints

Sl. no.	Chemicals	Concentration (%)	No. of splints tested	Visual appearance
1.	Hydrogen peroxide	15	250	Good
2.	Sodium meta-silicate + hydrogen peroxide	0.5 15	250	Excellent
3.	Sodium hydroxide + hydrogen peroxide	1 15	250	Excellent
4.	Sodium hypochlorite	15	200	Fair
5.	Sodium meta-silicate + Sodium hypochlorite	0.5 15	200	Fair
6.	Sodium hydroxide + Sodium hypochlorite	1 15	200	Fair
7.	Hydrogen peroxide + Sodium hypochlorite	15 15	500	Excellent

excellent results. However, splints need to be soaked in sodium meta-silicate solution for 20 to 25 min whereas soaking in sodium hydroxide needs only 30 s. Bleached splints were also subjected to strength tests that revealed that bleaching has no adverse effect on strength of match splints and bleached match splints passed the strength requirement as per IS 10374-1982 [5]. It was also seen that green bamboos are easier to bleach than dried bamboos.

The results of fire retardant chemical on after glow are summarized in Table 4. Figures in column 2 in the table show the effect of concentration of boric acid on the after-glow property. The experiments revealed that 0.5% of boric acid or phosphoric acid, and 0.75% boric acid/borax mixture solutions can be used for effective carbonisation of bamboo match splints, fulfilling the requirements of IS 2653-1993 [7]. However, a comparative analysis of general characteristics of boric acid and phosphoric acid (Table 5) brought out that phosphoric acid has several

Table 4.
Effect of fire retardant chemicals on after-glow period

Name of chemical	Concentration of chemical	After-glow period (s)
Boric acid	0.25	10
	0.50	1
	0.75	1
	1.00	1
	1.25	Negligible
	1.50	Negligible
	1.75	Negligible
	2.00	Negligible
Boric acid–borax	0.25	8
	0.50	1
	0.75	Negligible
	1.00	Negligible
	1.25	Negligible
	1.50	Negligible
	1.75	Negligible
	2.00	Negligible
Phosphoric acid	0.25	7
	0.50	Negligible
	0.75	Negligible
	1.00	Negligible

250 splints were treated with each chemical concentration.

Table 5.
General characteristics of boric acid and phosphoric acid

Factors	Boric acid	Phosphoric acid
Nature of material	Powder	Liquid
Transportation and storage	Can be manually unloaded; a small storage area protected from rain would do	Needs a pump for unloading; demands specially designed and fabricated tank for storage
Technical	Dissolution demands more power to get homogeneous liquid	Dissolution is easier as the material is liquid
Health hazards	Dust arising while charging would be hazardous	Produces strong pungent smells even in dilute hot condition; highly dangerous
Cost	Cheaper	Relatively costly

disadvantages and is more hazardous than boric acid. Hence, boric acid was selected for further experiments.

The experiments revealed that temperatures of 80°C–100°C for molten wax were suitable. In this range of temperature, a contact time of 10–20 s was required for adequate wax fixation. The pre-treatment with sodium meta-silicate or sodium hydroxide during the bleaching process also appears to be a positive factor in this regard.

Bamboo match sticks after head fixing was subjected to burning test. It was found that the sticks caught fire in a single stroke. The temperature goes up to 300°C which is comparable to the temperature attained in the case of wooden matchsticks available in the market. The burning was continuous and flame proceeded up to the end indicating that waxing of stick has taken place effectively. There was no after-glow and fire was seen to extinguish quickly.

5. CONCLUSION

From the studies carried out in the laboratory, it is clear that both *Bambusa bamboo* and *Dendrocalamus strictus* are suitable for making match splints. The method evolved at IPIRTI involves bleaching of bamboo splints of 1.5 by 1.5 mm cross-section and standard length with mixture of hydrogen peroxide, followed by carbonisation using boric acid. Adequate wax fixation could be achieved by dipping the bleached and carbonised bamboo match splints in molten wax at 80°C–100°C for 10–20 s. Head fixing was done using the standard chemicals and practices currently employed in the match factories. Limited factory trial done at a factory in Sivakasi established the efficacy of the method evolved for making matchsticks from bamboo.

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