Effects of Various Fibres in a Thin Biocomposite Material

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Abstract: There are a number of methods for producing biocomposite materials for different purposes. Wet lying methods are widely used in utilising especially short cellulosic fibres which offers random mixing and formation of homogenous filtrate over a travelling web. The method also contains wet pressing and controlled drying stages for achieving maximum fibre-fibre bonding. Fibres having different chemical compositions and physical properties behave differently in moving/draining suspensions which often give bad formation and heterogeneity in produced materials. Nevertheless, various fibres with different desirable properties are required to be finely blended in a suspension for getting targeted materials. This study investigated the effects of various fibres in a thin cellulosic material. It was aimed to see the possibility of using some short fibres, regarded as waste materials, in producing thin cellulosic matrix.

Keywords: Waste fibres, wet formation, cellulosic composites, tensile strength.

Introduction

Paper is probably one of the oldest thin biocomposite, the production of which is dated back to 105 BC. Tsua Lun, a Chinese scholar, initially boiled ramie, hemp and also later the inner bark of mulberry tree (kozo) to liberate the fibres. The pulp slurry, diluted fibre suspensions, was originally filtrated on a coarsely woven cloth and dried in the sun. The cooked rice water was also added into pulp slurry and/or applied to the surface of dried sheet to impart strength. The main principal in papermaking is actually not so changed since its first invention, but the technological movements are tremendous. Today, some modern papermills run at a speed of 120 Km/hour. The demand for raw materials is also fundamentally changed which forced the papermakers to search some alternative fibre resources as it was only nonwoody plants, waste robs and fabric before twentieth century. It was around 1850'ies when paper industry had to turn to forests and woods as main fibre resources. Since then, the demand for paper and many paperbased products has been increasingly growing. The types of paperbased products are also remarkably increased compared to its early use. The paper is in all parts of our daily life now (Kocurek, 1983; Smook, 1992).

Currently, paper recycling and search for alternative fibre resources take great attentions from industry and scientists. The waste paper recycling is reported to supply around 42 percent of world pulp demand. Pulp made from non-woody plant is unfortunately recorded to be only 4 percent of total world pulp consumption (Hurter and Riccio, 2006). The figure was quite big and significant in some parts of the world in the past. In Chine and India, for instance, wastes from agricultural activities were utilised to produce up to 73 and 56 percent of countries total pulp consumption respectively for some time ago (Tutus and Karademir, 2002). There have been numerous studies published on subjects dealing with the optimum pulping conditions of alternative fibre sources for paper making (Sharifah and Ansell, 2004; Tutus and Eroglu, 2004; Copur, Tozluoglu and Karademir 200).

In the papermaking process, huge amount of water is used. System actually works with water as the paper is simply made through wet formation. In terms of formation quality, the behaviour of fibres and other ingredients in slurry are crucially important. Homogenous distribution of components in the slurry should be maintained. Mechanical properties of end-products depend on the both fibre strength and interfiber bond strength (I'Anson et al, 2006). Some dry and wet strength additives are used to produce stronger paper.

In this study, some alternative fibrous materials (ceramic fibres, wools, wastes from yarn production and cotton dust) were used in the production of a thin board as biocomposite. The main focus was given on the changes of sheet strength. The findings are thought to offer useful information to those working in similar areas.

Experimental Materials and Methods

Fibres

Ceramic fibres, wool, yarn wastes and cotton dusts were used as alternative papermaking materials in this study. The control sample and main matrix with blend of alternative fibres was made of pulp obtained from old corrugated board. Materials were firstly cut in 3 cm length, soaked in water overnight and beaten for 2 minutes in a PFI mill in accordance with Tappi T 248 sp-08 method. Cotton dust was not beaten as it was already in quite small sizes.

Handsheets Making and Testing

Pulp slurries were prepared at % 0,5 consistency and control sheet was made from pulps of old corrugated boxes at a grammage of 100 g/m^2 according to Tappi 205 sp-95 method. Alternative pulps used were blended with control pulp at %15 and %30 levels and various thin biocomposites were produced by wet formation.

Sheets were conditioned in accordance with Tappi T 402 om-88 method at 23±2°C and 65±2% relative humidity for at least 24 hours before testing. The tests done to determine some physical properties of sheets were tabulated with relevant standards as below (Table 1).

Tests	**Standarts**
Beating/Pulping	Tappi T 248 sp-08 (PFI method)
Handsheet making	TAPPI T 205 sp-95
Paper Conditioning	TAPPI T 402 om-88
Air permeability (ml/min)	TAPPI T 460
Tensile index (Nm/g)	TAPPI T 494 om-88
Breaking length (m)	TAPPI T 404 om-87
Burst index ($kPam^2/g$)	TAPPI T 403 om-91

Table 1: Tests and methods followed during papermaking and analysing.

Results

Pulp Suspension and Sheet Formation

Fibres from softwoods are named as long fibres while those obtained from hardwoods are regarded as short fibres. Length of long and short fibres would be on average 3 mm and 1.5 mm respectively. Long fibres contribute sheet strength while short fibres give smoother and denser sheets. It is known that long fibres tend to get entangled and form floks of big fibre groups in a suspension at a higher speed compared to those of short fibres. Therefore, the consistency of long fibre suspension must be adjusted at quite low level to be able to have a well distributed stock, hence a good formation.

It is noted that all fibres used in this study negatively affected pulp suspensions giving cloudy apperance and heterogenous clumpy fibre groups. Alternative fibres were actually beaten to get an extra fibrillated surface that was in favour of homogenous suspension and also stronger sheets. Differences between fibres such as density, wettability, length, physical structure gave heterogenous suspension. Cotton dust was noted to be well mixed with control pulp out of all studied here. It was attributed to the smaller fraction of cotton dusts and similar structures to wood fibres. The effects of fines like cotton dust were studied by some researchers in details (Retulainen et al, 2002; Lin et al, 2007; Xu and Pelton, 2005). Ceramic fibres were broken down to filler after mechanical action in a lab disintegrator hence were used like fillers.

Air Permeability

Addition of alternative materials in controlled pulps resulted in significant reductions of sheet air resistance as seen in figure 1. Ceramic fibres in the form of filler were noted to reduced air resistance lower then all other materials. Wool fibres on the other hand remarkably reduced the air resistance of sheets. Result suggests that all materials added to control pulp disturbed the formation quality of sheets. The higher air resistance value of control sheet indicates the firm and dens fibre matrix. Whereas the structure seems to be loosen up and become fluffy as a result of especially wool addition. Wool fibres probably interfered with wood fibre bonding and made them in a sense separated giving a permeable material.

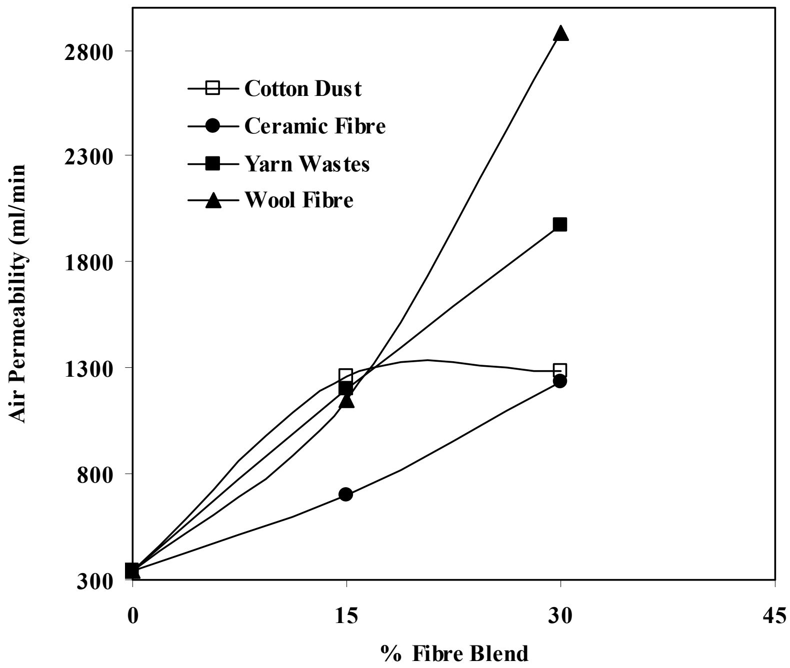

Figure 1: Fibres added increased the air permeability.

Mechanical Properties

Tensile index, breaking length and burst index values of all sheets were plotted in figure 2, 3 and 4 respectively. As it is clearly seen in figures, the addition of alternative materials studied here dramatically reduced the mechanical strength of resultant products. It is believed that the alternative fibres did not develop any significant internal bonds between both themselves and fibres of control papers. Furthermore, they actually interfered with fibre-fibre bonding.

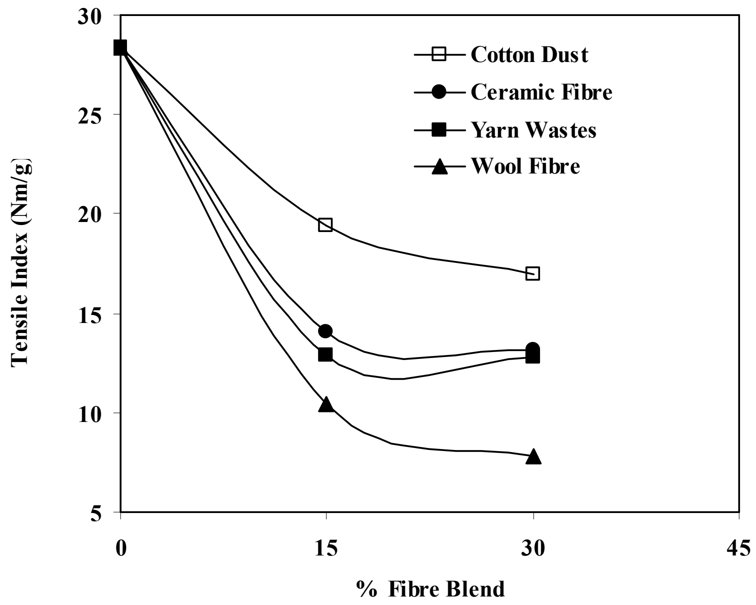

Figure 2: Tensile index was badly damaged with fibre blends.

Out of all materials studied here, the highest reduction in sheet strength was noted with the addition of wool fibres. Negative effect on strength by the addition of cotton dust was recorded to be smallest compared to the changes due to other fibres. Differences between the effects of yarn fibre and cotton dust were believed to be mainly due to the particle sizes. The chemical composition of both yarn and cotton dust are not so different since they are compost of almost pure cellulose molecules. The sizes, however, were significantly different as yarn was made of long cotton fibres and cotton dust was quite small in sizes as such it can be regarded as fine in a real papermaking environment. There are various reports on the effects of different fines on paper strength (Retulainen et al, 2002; Lin et al, 2007; Xu and Pelton, 2005). Fine improves paper smoothness and air resistance if retained and evenly distributed in paper structure. It may develop paper strength too if it has plenty hydroxyl groups. Cotton dust in this case did not improve the sheet strength. It suggests that the bond strength between fibres in control pulp were greater than that developed between both cotton dusts and fibres in controlled sheets.

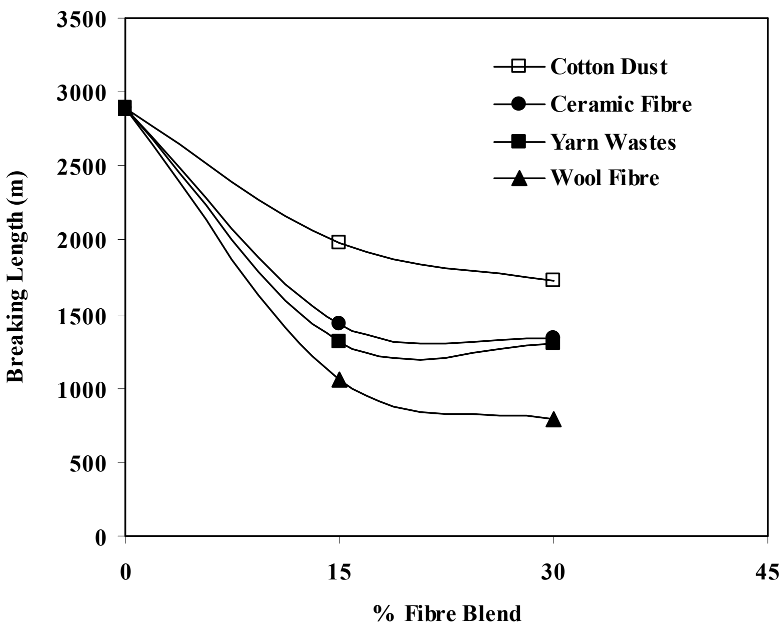

Figure 3: Fibre blending reduced the breaking length in a great deal.

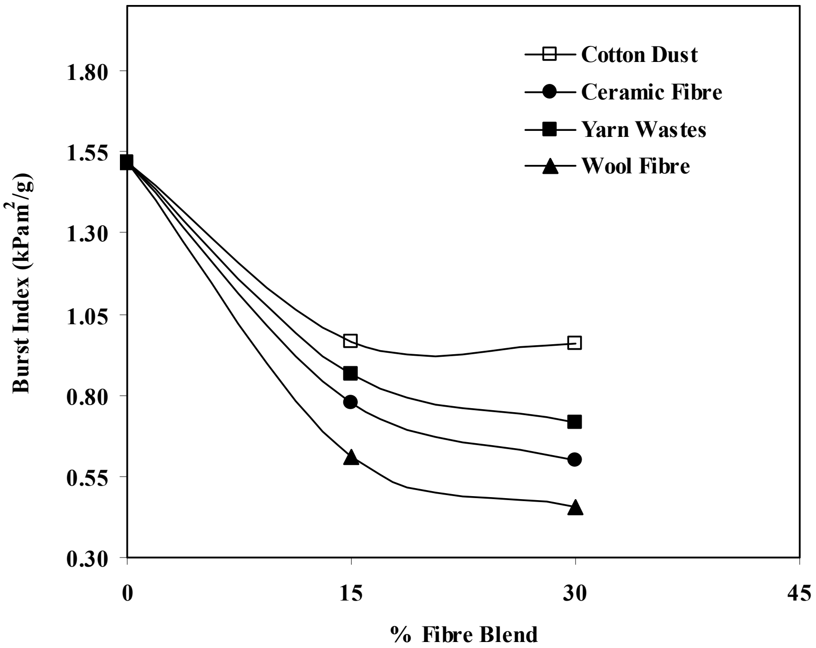

Figure 4: Fibre blending destroyed the burst index value of control sheet.

Wood fibres from softwood and hardwoods have been extensively used in the production of paper, board and fibreboards in wet forming system. The strength of end products depends on both the strength of individual fibres and interfiber bond strength. The latter is governed by the amount of hydrogen bonds to be developed between fibres during pressing and especially drying stages (I'Anson et al, 2006). Therefore fibres having ability to form hydrogen bonds can contribute strength of end products. It would be said that the materials used in this study did not produce enough hydrogen bonds either between themselves or between fibres of controlled pulp. In such situation, extra bond enhancer must be used such as starches, resins and bonding agents.

Conclusion

Four materials, ceramic fibres, wool, yarn wastes and cotton dusts were studied to find out if they may be used in the production of thin biocomposites like paper, board and fibreboard in wet lying system. The materials were blended with control pulps at two proportions as %15 and %30 and a number of sheets were formed. Attention was especially given to the changes of mechanical properties of sheets as a result of material blending. It was in general found that all material used here remarkably changed the sheet properties. The sheets air resistance and three mechanical strength values were greatly reduced. It is suggested that in order to increase the formation quality of blended pulps, the fibres should be made in similar sizes. Dry strength agents must be also used if the mechanical strength properties are important for end users of such products.

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