Wheat Straw Pulp as Reinforcing Aid for Recycled Softwood Pulp

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ABSTRACT

Repeated papermaking reduces the bonding potential of pulp fibers. For efficient utilization of secondary fibers, it is important to find ways to recover this lost potential. Various methods are in practice; mechanical refining, chemical additives, enzyme treatment, physical fractionation, and blending. Blending of a virgin pulp with recycled fibers helps in upgrading the recycled pulps. Generally, the pulps used for blending are stronger than the recycled pulps; mostly virgin softwood pulps are used. In the present work, an attempt is made to study the usefulness of blending wheat straw pulp for upgrading recycled softwood pulps.

Wheat straw fibers are remarkably good in fiber bonding potential, which they retain even on repeated papermaking. Blends of wheat straw pulps and recycled softwood pulps can combine the benefits of high bonding potential of wheat straw fibers and high inherent strength of softwood fibers to result in a more economical and environmentally benign papermaking furnish. In this paper, experimental observations on the effect of blending wheat straw pulp in different proportions on the physical properties of recycled softwood pulps have been discussed. The results show that wheat straw pulps enhance strength of recycled pulps and the blends containing about 40 to 60% wheat straw pulp offer the best combination of tensile and tear strengths.

INTRODUCTION

Repeated papermaking reduces the bonding potential of pulp fibers. Chemical softwood pulps experience very significant loss of bonding strength on recycling, though they are among the strongest pulps available for papermaking when used first time. Many research studies devoted to the evaluation of effect of recycling on the strength and other papermaking properties of different kinds of pulp fibers have been reported (1-9). A high amount of research efforts has also been made to find ways to recover the lost potential of such recycled fibers. Various methods have been suggested and used in practice; the notable ones are mechanical refining, chemical additives, enzyme treatment, physical fractionation, and blending. The commonly employed techniques of strength improvement of recycled pulps, namely, mechanical refining and chemical additives are not without processing difficulties. Refining enhances tensile and burst strengths (6-8) of recycled pulps by increasing fiber flexibility and swellability, but at the cost of severe fragmentation of the hornified brittle fibers (8-10) that makes the pulp slow to drain in the forming section of paper machine. Although strength aids help to some extent in increasing fiber bonding without greatly affecting the pulp freeness, they cannot be used as full substitute to refining as they cannot restore the swelling ability of hornified fibers, and the penetration of their large molecules into micropores in the cell wall structure is limited (11-13). Some studies (12,14-17) suggest that enzyme hydrolysis can increase freeness of recycled pulps, but opposite views exist on the effect of enzyme on strength properties. Some workers (14,15,17) claim that enzyme treatment of secondary fibers results in strength enhancement while Oltus et al (18) report complete fiber disintegration due to enzymatic hydrolysis of pulps. Mechanical refining preceding enzyme treatment can give better physical properties at same freeness level (17).

Since the effect of recycling is more detrimental to shorter fibers than to longer fibers of a pulp (8,19,20), refining is capable of restoring the swelling of long fiber fraction more than the swelling of fines (8,20). The fines generated during refining (secondary fines) are helpful in enhancing the strength properties but are equally important in reducing the pulp freeness (20,21). Fractionation involving separation of long fiber fraction from the recycled pulp, refining that separately, and remixing that again with the finer fraction can be a viable method to upgrade low quality recycled pulps (2,4,20).

Blending of virgin pulp with recycled fibers offers another viable option for upgrading the recycled pulps. Generally, the pulps used for blending are stronger than the recycled pulps; virgin softwood pulps are most widely used for such application. In an earlier study (5), we observed that wheat straw pulps had some extraordinary properties. In the present work, an attempt is made to study the interactions between wheat straw pulp and recycled softwood pulp.

Wheat straw fibers are weaker (in intrinsic strength) than softwood fibers. Wheat straw pulps make paper that has low tearing and folding strength. They drain poorly on the paper machine. But, a remarkably good thing about wheat straw pulps is their high fiber bonding potential and their ability to retain this potential even on repeated papermaking (5). Due to this high bonding potential, wheat straw pulps can have as high tensile strength as softwood pulps have.

Blends of wheat straw pulps and recycled softwood pulps can combine the benefits of high bonding potential of wheat straw fibers and high inherent strength of softwood fibers to result in a more economical and environmentally benign papermaking furnish. The high bonding potential of wheat straw pulp should be able to make up for the loss of bonding on recycling of softwood fibers. However, not many studies of this nature are available in literature. Arvamuthan and Greaves (21) recycled a 70/30 mixture of softwood and wheat straw pulps and observed that the handsheets of this mixture had dry strength properties comparable with 100% softwood pulp even after four stages of recycling. At equal freeness values, the mixed pulp had better burst and tensile index than the softwood pulp had. They presumed that the presence of fines in wheat straw pulp helped in fiber bonding.

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Table-1 Proximate analyses of wheat straw

Hot Water Solubility (%)	9.7
1% NaOH Solubility (%)	40.1
Ash (%)	8.23
Alcohol Benzene Solubility (%)	5.45
Holocellulose (extractive free) (%)	72.94
Alpha Cellulose (extractive free) (%)	41.6
Lignin (extractive free) (%)	21.6
Pentosen (%)	19.7

Table-2 Conditions of Pulping of wheat straw

Alkali charged (%)	15
Bath ratio	1:5
Cooking Temp. °C	165
Time to Temp. (min)	72
Time at Temp. (min)	30
Screened yield (%)	41.92
Rejects (%)	5.61
Kappa Number	19.4

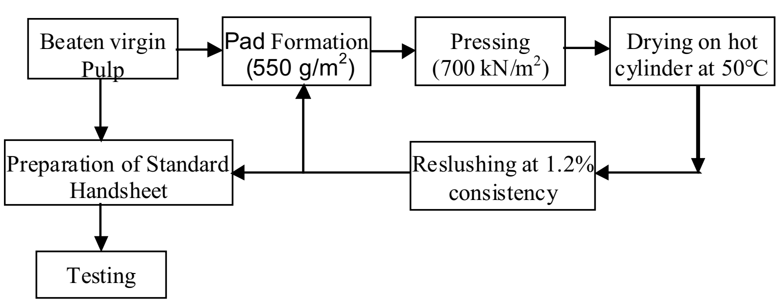

Fig.1: Schematic representation of recycling of pulps

In this paper, experimental observations on the effect of blending wheat straw pulp in different proportions on the physical properties of recycled softwood pulps have been discussed. The results show that the blends containing about 40 to 60% wheat straw pulp and remaining recycled softwood pulps offer the best combination of tensile and tear strengths. Possible mechanisms for the synergy between different types of pulps in a blend will be discussed in a future paper.

EXPERIMENTAL WORK

Pulps

The softwood pulp used in this study was a commercial bleached kraft pulp available in sheet form. The wheat straw pulp was prepared in the laboratory. The wheat straw collected from a thrashing mill belonged to the wheat varieties commonly grown in western Uttar Pradesh. Before processing further, the extraneous dirt from the wheat straw collected was removed by dry-screening on a 20-mesh screen. The proximate analysis of the wheat straw was determined as given in Table-1. Appropriate Tappi standard procedures (22) were used for the analysis. The wheat straw was cooked in a laboratory batch digester by soda process, washed, and screened using the conditions shown in Table-2. The wheat straw pulp produced in the laboratory was bleached in the laboratory to a targeted brightness of +80% using CEHH sequence at the conditions given in Table-3. The wheat straw and the softwood pulps were beaten in a valley beater.

Recycling

The pulps were subjected to repeated wetting and drying cycles as shown in Fig.-1. A portion of the beaten pulp was used for making standard handsheets of 60±2 g/m2 using SCAN M5:76 (23) and the remaining portion was used for making thick pads of 550 g/m^2 on the same sheet-making machine. The backwater was re-circulated during the making of sheets and pads. The pads were wet pressed (700 kN/m^2) and dried on a heated cylinder at 50 C in contact with gloss plates. For subsequent cycles the pads were reslushed in the laboratory disintegrator at 1.2% consistency and remade into handsheets and pads without beating between the cycles. The standard handsheets were used for evaluation of various properties of the pulps. The sheets were tested using Tappi standard procedures. For determination of water retention value (WRV) of pulps, a centrifugal force of 3000N for 20 minutes was used. Table-4 shows effect of recycling on different properties of softwood and wheat straw pulps.

Blending

The virgin wheat straw pulp was blended with virgin/ once recycled softwood pulps in different proportions

Table-3 Conditions of Bleaching of wheat straw pulp

	C-Stage	E-stage	H_1-stage	H_2-stage
Consistency (%)	3	10	10	10
Temperature °C	25 (ambient)	60	40	40
Retention time (min.)	45	60	150	150
End pH	2-3	> 9.5	9.5-10	9.5-10
Chlorine charged (%)	5.25	-	1.5	0.75
Alkali Charge (%)	-	2.65	To adjust pH	To adjust pH
Final brightness of bleached pulp (%)				80

Table-4 Effect of recycling on softwood and wheat straw pulps

Properties	Softwood Pulp			Wheat straw Pulp		
	0	1	2	0	1	2
CSF, ml	300	390	420	210	215	210
Tensile Index, N m/g	85.1	62.4	55.9	82.0	76.5	74.6
Tear Index, mN m^2/g	11.12	13.55	15.2	3.82	5.92	5.78
Zero-Span Tensile Index, N m/g	107.8	114.9	116.2	90.2	86.2	87.4
Folding Endurance	2.22	2.20	2.1	1.52	1.71	1.75
Bulk, cm^3/g	1.53	1.69	1.70	1.22	1.42	1.43
WRV, (g/100g of pulp)	176.7	138.5	132.6	250.8	195.8	166.9
Note: 0 – virgin cycle, 1 – first recycle, 2 – second recycle						

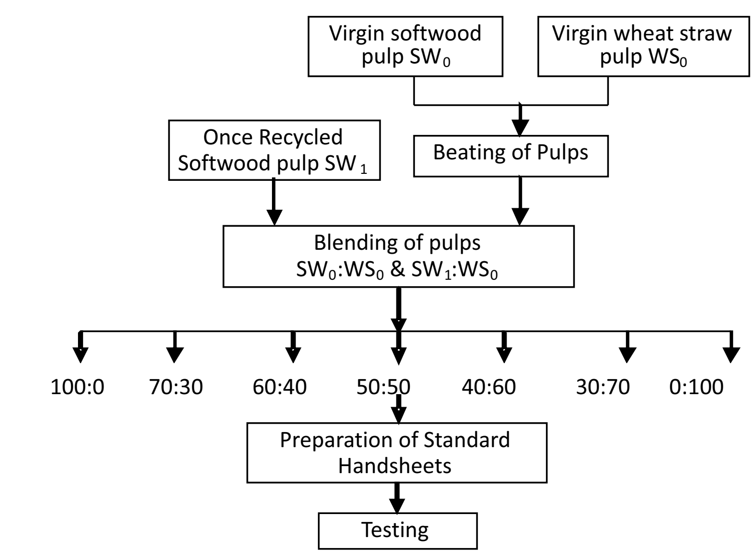

Fig.2: Schematic representation of blending of pulps

as shown in the Fig.-2. The pulps were diluted to 0.3% consistency before blending to minimize errors in measurements. Standard handsheets were prepared from these blends to evaluate various properties.

DISCUSSION

Recycling behavior of softwood and wheat straw pulps

Table-4 shows the properties of softwood and wheat straw pulps for three cycles. In the virgin state, the wheat straw pulp had tensile strength close to that of softwood pulp but it was much weaker in tearing strength. Softwood fibers were stronger than the wheat straw fibers as evident from higher zero span tensile index for softwood pulps. A high tensile strength for wheat straw pulp, in spite of week fibers, may be attributed to its high fiber bonding ability. Also, the low tearing strength of wheat straw pulp is attributed to short fiber length of wheat straw. As expected, the softwood pulp had greater folding endurance and bulk, and a lower water retention value (WRV) when compared with wheat straw pulp.

Recycling caused a much greater loss in tensile and burst strength for the softwood pulp than it did for the wheat straw pulp. The high recycling potential of wheat straw pulp, i.e., less reduction in tensile strength on recycling, could be attributed to its high -cellulose content and its ability to retain fines during recycling (5,21). Cao et al (24) found that pulps containing high amounts of xylan showed high recycling potential as xylan molecules present between the cellulose microfibrils in cell wall of a fiber prevented them from bonding with each other (self-association) during drying in subsequent cycles. Thus, the microfibrils were left relatively loose so that the fibers could regain their flexibility upon rewetting.

Tear index of both the softwood pulp as well as the wheat straw pulp increased with recycling. The effect of recycling on folding endurance was not significant for both the pulps.

Recycling did not have a significant effect on zero-span tensile strength either for softwood or for wheat straw pulp. The difference in the mean values of zero-span tensile index (ZSTI) at three cycles was statistically insignificant at 95% confidence level (t-statistic for comparison of means). Earlier studies also indicate that the effect of recycling on zero-span tensile strength (ZSTS) was unpredictable; Howard and Bichard (1) found no change in ZSTS on recycling of eleven different pulps, while Mckee (6) and Horn (25) found that ZSTS increased on recycling of pulps.

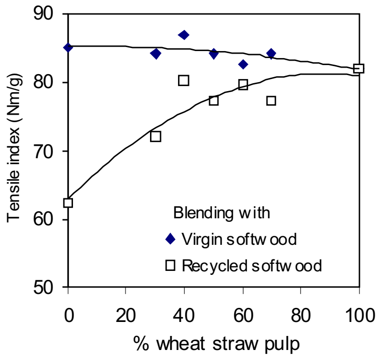

Fig.3: Effect of blending of virgin wheat straw pulp on tensile strength

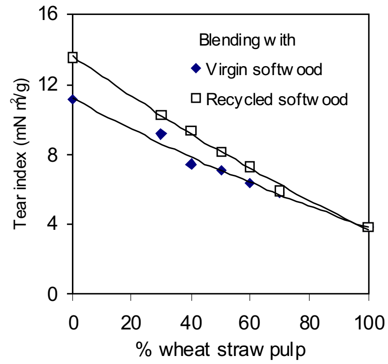

Fig.4: Effect of blending of virgin wheat straw pulp on tear index

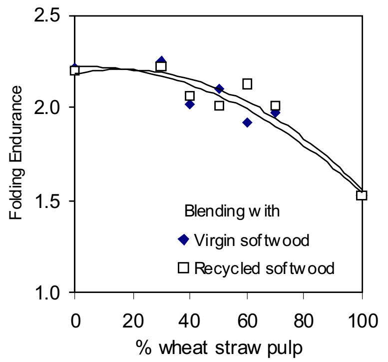

Fig.5: Effect of blending of virgin wheat straw pulp on folding endurance

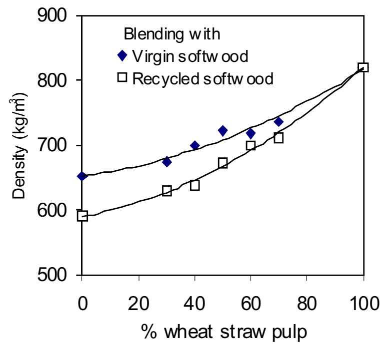

Fig.6: Effect of blending of virgin wheat straw pulp on apparent sheet density

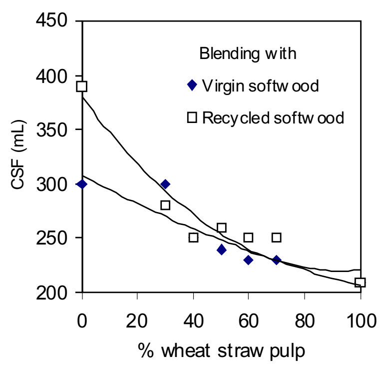

Fig.7: Effect of blending of virgin wheat straw pulp on CSF of the mixed pulp

Effect of Blending on tensile index

Fig.-3 shows tensile index of different blends of softwood and wheat straw pulps. The tensile index values were nearly the same for the virgin wheat straw pulp, for the virgin softwood pulp, and for different blends of these pulps. Addition of wheat straw pulp to the recycled softwood pulp appeared to be particularly advantageous. The tensile index for the blend of recycled softwood pulp and wheat straw pulp rose sharply with the increase in percentage of wheat straw pulp. The tensile index values for such blends were well above the line joining the points for recycled softwood and wheat straw pulps. The points on such a line will represent the weight weighted mean tensile strength, i.e., the mean value calculated from the tensile strength of the two types of pulps each having its contribution in proportion to its weight in the mixture. A statistical analysis of the mean values of the tensile index for different blends confirmed that the difference in values was significant at 95% confidence level, i.e., the probability that the difference had arisen by chance was less than 5%.

Effect of Blending on tear index

Fig.-4 shows tear index of different blends of softwood and wheat straw pulps. The tear strength of the softwood pulp was much greater than that of wheat straw pulp and it increased further on recycling. The effect of adding wheat straw pulp to softwood pulp (virgin or recycled) did not appear as advantageous for tear strength as it did for the tensile strength. The tear index of the blend decreased as the percentage of wheat straw pulp was increased nearly following the weight weighted mean of tear strengths of the two pulps. The same trend was visible for the blends of wheat straw pulp with virgin softwood pulp as well as with recycled softwood pulp. This is because the tear strength is largely dependent on the fiber length (26,27).

Effect of Blending on other physical properties

Fig.-5 shows that the folding endurance of the blends of softwood and wheat straw pulps depended largely on the folding endurance of the softwood pulps. When the proportion of the softwood pulp in the blend fell below 30%, the folding endurance of the blend decreased sharply. Figures 6 and 7 show that the percentage of wheat straw pulp in the blend affects the apparent density of the handsheets and the freeness of the blended pulp slurry in a manner as expected. Increased percentage of wheat straw pulp results in an increased apparent density because the wheat straw pulp besides being short fibered pulp increases fiber bonding of the mixture. The Canadian standard freeness of the pulp decreases as the percentage of the wheat straw pulp is increased.

CONCLUSIONS

1. Wheat straw pulps have a high fiber bonding potential even though the fibers are much shorter and weaker than the softwood fibers. Because of their fiber bonding ability, wheat straw pulps have tensile strength close to that of softwood pulp but have lower tearing strength. Blending with wheat straw pulp can considerably enhance the strength of recycled softwood pulps.

2. Wheat straw pulp acts as reinforcing pulp for the recycled softwood pulps. The tensile index for the blend of recycled softwood pulp and wheat straw pulp rises sharply with the increase in percentage of wheat straw pulp. The tensile index of the blend may even be grater than the stronger of the two components. However, for the tear strength, the addition of wheat straw pulp to softwood pulp is not as advantageous as it is for the tensile strength. The tear index of the blend decreases as the percentage of wheat straw pulp is increased nearly in proportion to the weight of the wheat straw pulp added.

3. Blends of wheat straw and recycled softwood pulps bring together high bonding ability of wheat straw fibers with long and strong softwood fibers to obtain an acceptable tensile-tear combination. For countries like India, such a furnish should be economical as the cost of virgin softwood pulp is more than the cost of wheat straw or recycled softwood pulps.

4. The results show that the blends containing about 40 to 60% wheat straw pulp and remaining recycled softwood pulps offer the best combination of tensile and tear strengths.

5. Wheat straw pulps have a high recycling potential as they do not suffer as much loss in tensile and burst strength as do the softwood pulps. Blends of pulps containing wheat straw fibers as one of the components should have a high recycling potential because the wheat straw fibers will retain their bonding ability even on recycling.

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