THE EFFECT OF USING WHITE BIRCH ON MECHANICAL PROPERTIES AND FIBER LENGTH DISTRIBUTION OF MIXED HARDWOOD CMP PULP

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In this research, the effects of combining white birch species with hornbeam and beech on the strength properties and fiber length distribution of the CMP pulp in Mazandaran Wood and Paper Industries (MWPI), was investigated. CMP pulp was prepared based on the conditions of liquor to wood ratio: 7/1, sodium sulfite: 20% based on OD wood chips, temperature: 160 °C and cooking time: 85 to 135 minutes to achieve CMP pulp yield of 85 % by using imported birch at 10, 20, 30, and 40% in combination with 60 to 90% hornbeam and beech. CMP pulp in MWPI was produced using 75% hornbeam and 25% beech under similar conditions. After defibration of cooked wood chips in a 20-inch defibrator, it was refined by PFI mill refiner up to the freeness of 300 mL CSF. The results of the standard handsheet analysis showed that using 10 to 40% birch species resulted in a significant reduction of pulp shives (0.36%), higher long fibers fraction increase of medium fiber (59.9%), as well as short fibers (16.3%) and reduction of fines (9.8%) fractions in pulp furnish, as compared with CMP pulp from MWPI. In addition, using different percentages of birch in combination with hornbeam and beech resulted in improving the papers' strength properties such as tensile index (69.4 Nm/g), burst index (582.4 kPa.m^2/g), tear index (16.6 mN.m^2/g), and stiffness (36.7 mN) as compared to MWPI's CMP pulp.

Keywords: White Birch; Strength Properties; Fiber Length Distribution; CMP Pulp.

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INTRODUCTION

Considering the increasing limitation of supplying forest softwood and also different hardwood species for pulp and paper industries on a global scale (including Iran), utilization of fast-growing hardwood species of spruce, willow, and eucalyptus will play an important and promising role in supplying the requirements of wood-based fibers for pulp and paper industries, especially in those developing countries which have limited forest resources. The wood fibers of hardwoods are shorter with less diameter than the fibers of softwood species, resulting in production of papers with inferior strength properties. Although hardwood fibers possess some desirable properties that are especially suited for producing smooth papers for printing and writing, they tend to produce paper products with more uniform formation, compared to softwood fibers. Another reason for increasing the application of hardwood species in pulp and paper industries is that considering the development of new processes for

pulp production, it has been possible to produce paper pulp with suitable optical strength properties, together with low productivity costs and low financing using hardwood species (Resalati 2008; Feizabadi 2002). During the past 50 years, many various species and colonies of foreign *Populus* have been imported to Iran. The results show that different poplar clones of *P. deltoides* and *euroamericana* have been successfully grown in Northern provinces of Iran, including two important clones of *P. deltoides* 77.51 and *P. euroamericana* 2-214. These species can entirely supply the required suitable raw material for Iranian pulp and paper industries. Among different hardwood species, fast growing poplar and eucalyptus species are planted and extended in vast areas, especially in the developing countries such as Iran. By increasing the yield of CMP pulp prepared from a mixture of 75% hornbeam and 25% poplar, the bulk and opacity are improved. These properties were even better and more desirable than the mixture of 75% hornbeam and 25% poplar at constant freeness of 300 mL, CSF. Among the conventional chemi-mechanical processes, the condition of CMP pulp production from hardwood species is more critical than other processes. The CMP process, especially the cooking liquor of sodium sulfite – bisulfite without the presence of soda (MWPI CMP pulping liquor) is less efficient compared to chemi-mechanical processes, with more chemical consumption, higher reaction time, and chemical treatment temperature (Pourmousa 1998; Rasouli 2002). The results of assessing the mechanical properties of the papers produced from CMP pulp prepared from *deltoides* and *euroamericana* showed that the paper strength properties were improved when treatment time and temperature were increased. In general terms, papers from *P. euroamericana* species will show a better mechanical strength compared to *P. deltoides* (Nazarnezhad 1996).

Utilizing the species with lower densities such as fast growing spruce and paulownia up to 25% of the final CMP pulp mixture compared to MWPI's wood mixture (75% hornbeam and 25% beach) resulted in production of papers with lower bulk, opacity, and higher bonding ability leading to superior tensile and burst strengths at similar or lower tear strength. By adjusting the cooking conditions and controlling the yield of CMP pulp (containing 75% hornbeam and 25% beech and poplar), it is possible to produce papers with suitable optical and strength properties at lower energy consumption for preparation of wood chips, lower steam and bleaching chemicals, and better fiber distribution leading to higher bonding in paper (Resalati 2008).

By using fast-growing species of poplar in combination with higher density forest species, the energy required for refining in constant freeness will be increased. In this regard, the energy required for *P. euroamericana* was more than that of the *P. deltoides*. In case of using maple species in the mixture of the species used for producing CMP pulp, the consumed refining energy for reaching a similar freeness level decreased but the resulting pulp had a higher percentage of shives or uncooked fiber bundles (Feizabadi 2002). Various grades of writing and printing papers can be obtained by chemi-mechanical pulping of *Eucalyptus grandis* using 5.2% sodium sulfite based on OD wood chips and 110 °C cooking temperature (Valade *et al.* 1984).

Due to recent shortages in fiber supply from local hardwood species, paper production rates at MWPI, the largest Iranian paper manufacturer, has declined. The present paper studies the effect of using imported birch as part of raw material mixtures, on strength properties and fiber length distribution of CMP pulp for making newsprint.

EXPERIMENTAL

Wood Chips Preparation

Samples were prepared from a wood preparation unit in MWPI. These samples consisted of imported white birch species from Russia and also MWPI's produced wood chips (hornbeam and beech), which are used for production of CMP pulp for manufacturing newsprint. The samples were prepared in a completely random manner from the wood chip piles at MWPI. By changing the consumption rate of birch wood chips in combination with hornbeam and beech, the produced CMP pulps were analyzed compared to MWPI's CMP pulp (75% hornbeam and 25% beech).

Production of CMP Pulp

CMP pulp was prepared based on the following conditions: yield: 85%, liquor to wood ratio: 7/1, sodium sulfite addition level: 20% based on OD wood chips, cooking temperature: 160 °C, and cooking time: 85 to 135 min. Birch wood chips were used from 10 to 40% combined with 60 to 90% hornbeam and beech. CMP pulp was prepared by combining 75% hornbeam and 25% beech species at MWPI as a control pulp. It is worth mentioning that in all combinations of the wood chip mixtures used for making CMP pulp, the ratio of 75% hornbeam and 25% beech has been constant for these species. After defibration of chemical treated wood chips (in 5 steps at local made defibrator), refining of the defibrated pulp was performed by a PFI refiner to reach a constant freeness level of 300 mL, CSF.

Fiber Fractionation and Handsheets Preparation

Handsheets were prepared according to TAPPI T205 SP-02 standard at a target basis weight of 60 gsm from each pulping condition. Pulp shives (the fibers collected on screen with pore size of 0.15 mm) was measured using a master screen device. Length distribution of fibers including long fibers (the fibers collected on mesh 28 and 48), medium fibers (the fibers collected on mesh 100), short fibers (the fibers collected on mesh 200) and fines (the fibers passed from mesh 200) were measured by the aid of Bauer-McNett type classifier according to TAPPI T233 cm-82 standard. The mechanical properties of the handsheets including tensile index and stiffness were evaluated based on TAPPI T404 om-1 standard, and burst and tear indices were measured based on TAPPI T403 om-04 and TAPPI T414 om-04, respectively. The mechanical properties of the papers (with 5 replicates) produced from CMP pulp and the fiber length distribution were compared by considering different percentages of birch in combination with MWPI's paper pulp (75% hornbeam and 25% beech).

Statistical Analysis

Sampling of the wood-chips was performed in a completely random manner. In order to investigate the effects of birch wood chips on the quality of CMP pulp, statistical variance analysis method and the Duncan test was used for comparing the average values.

RESULTS AND DISCUSSION

Fiber Length Distribution

Pulp shives

Increasing the consumption rate of imported birch from 10 to 40%, as compared to MWPI's CMP pulp, has shown a significant reduction in CMP pulp shive content. It must be reminded that based on the Duncan test, no significant difference was observed between the shive content of CMP pulps resulting from 20 to 40% imported birch at confidence level of 99%. The least amount of shive was 0.36 percent, which was related to CMP pulp obtained from replacing 30% imported birch. In general, using imported birch instead of hornbeam and beech in wood furnish composition for making CMP pulp resulted in significant reduction in the CMP pulp shives (Fig.1).

Long Fibers Fraction

Replacing 10 to 40% imported birch for production of CMP pulp, as compared to MWPI's CMP pulp, showed a significant increase in long fiber fraction of CMP pulp. Increasing consumption rate of imported birch up to 30% had resulted in lower long fiber fraction compared to MWPI's CMP pulp, whereas utilization of 40% imported birch increased the long fibers fractions which was statistically significant at 99% confidence level. That is, the highest percentage of long fiber (14%) has been obtained by using 40% imported birch in combination with 60% hornbeam and beech (Fig 2).

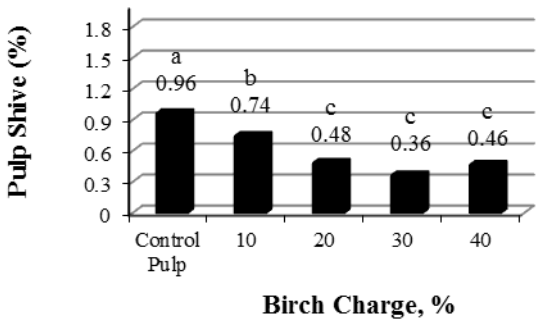

Fig.1. The effect of different charges of birch on pulp shive content.

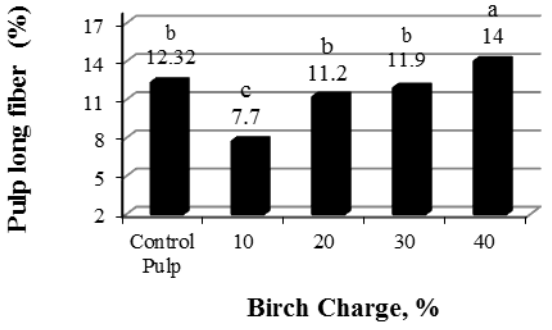

Fig2. The effect of different charges of birch on pulp long fiber fraction.

Medium fibers fractions

The variance analysis test for the percentage values of medium size fibers of CMP pulp showed that replacing the birch species with hornbeam and beech as compared to MWPI's pulp, caused a significant increase in percentage of pulp medium fibers. The results of the Duncan test showed that there was no significant difference between the percentages of

medium fibers fraction using 10 and 20% imported birch at confidence level of 99%. In general, by replacing 10 to 40% birch, it is possible to produce CMP pulps with a higher percentage of medium fibers (Fig. 3).

Short fibers fraction

As shown in Fig. 4, the results of replacing birch with hornbeam and beech in wood furnish composition to produce CMP pulps, resulted in a significant increase in the percentage of short fibers. Results of the Duncan test showed that no significant differences were found between the percentage of short fibers fraction in MWPI's CMP pulp and CMP pulp produced from 10 and 20% birch addition rates. However, significant differences at a confidence level of 99% have been observed in short fibers fraction between CMP pulps produced from other wood furnish compositions.

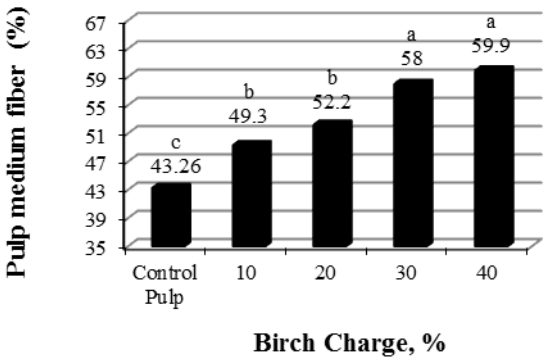

Fig.3. The effect of different charges of birch on pulp medium fiber fraction.

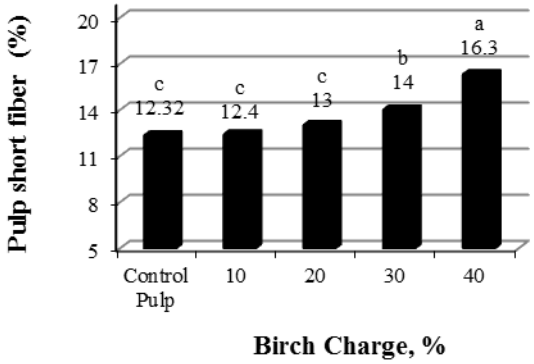

Fig.4. The effect of different charges of birch on pulp short fiber fraction.

Pulp fines

Utilization of 10 to 40% imported birch chips in combination with hornbeam and beech, as compared to MWPI's CMP pulp, resulted in a significant reduction in the amount of pulp fines (the weight percentage of pulp passed through mesh 200). The Duncan test showed that no significant differences at a confidence level of 99% were observed in fines fraction between the MWPI's CMP pulp and the CMP pulp produced from 10% birch addition. In addition, by increasing the consumption rate of imported birch from 10 to 40%, the pulp fines content was reduced significantly (9.8% fine at 40% imported birch addition). The results obtained indicated that with partial displacement of imported birch chips up to 40 % with hornbeam and beech, it is possible to produce CMP pulps with higher percentages of long and medium fibers fraction and lower fines and, as a result, produce a better fiber length distribution (Fig. 5).

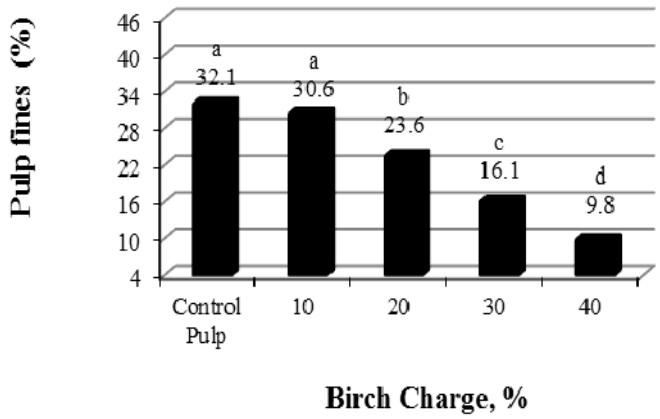

Fig.5. The effect of different charges of birch on pulp fine content.

Strength Properties

Assessing the results of partial replacement of birch in the furnish composition of hornbeam and beech to make CMP pulp showed that tensile, breaking length, and burst and tear strength of CMP pulp were significantly increased by increasing the addition rates of imported birch up to 40 %, as compared to MWPI's CMP pulp (see Figs. 6-9). In general, improvement of bonding related strength such as burst, tensile, and breaking length indices is related to fiber structure including initial fiber length, wall thickness, and fiber classification (or distribution of fiber length) in pulp furnish (Kostiainen *et al.* 2008; Resalati 2005). Birch wood has a lower diameter, thinner cell wall, and longer fiber compared to hornbeam and beach fibers. As a result, its fibrillation is improved due to more flexibility and collapsibility of birch fibers, which lead to higher strength properties (Kostiainen *et al.* 2008; Riikonen 2004; Scott 1940; Rasouli 2002; Resalati 2005). In addition, CMP pulps containing different percentages of birch fibers resulted in papers with higher tear strength because birch pulps had higher average fiber length and also lower fines, compared to the control MWPI CMP pulp.

Tensile stiffness

The CMP pulp resulting from 10 to 40% birch in combination with hornbeam and beech woods, as compared to control MWPI's CMP pulp, showed significant improvement in tensile stiffness at a confidence level of 99% (Fig. 10), and highest tensile stiffness of 7.36 mN was obtained at 40 % birch content. Inter-fiber bonding could be improved when the fibers have smaller diameter and lower cell wall thickness due to better flexibility/collapsibility which together with lower fine and higher fiber length lead to increased tensile stiffness of paper (Resalati 2005).

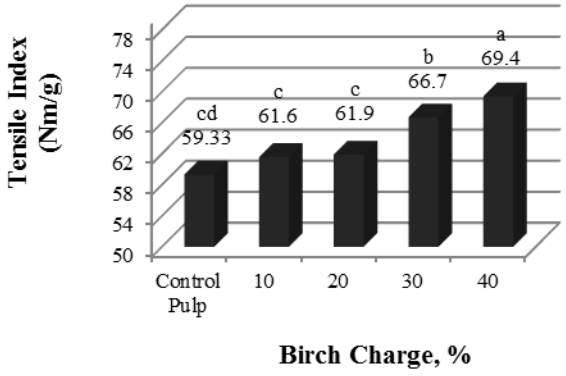

Fig.6. The effect of different charges of birch on pulp tensile index.

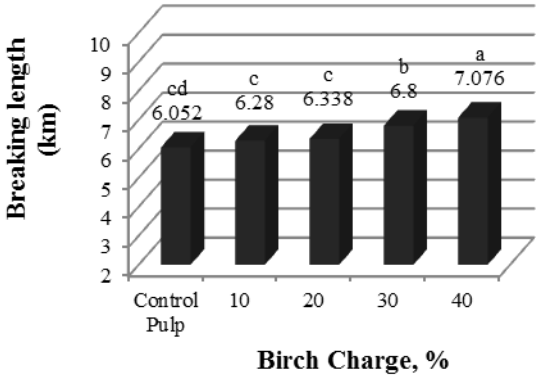

Fig.7. The effect of different charges of birch on pulp breaking length.

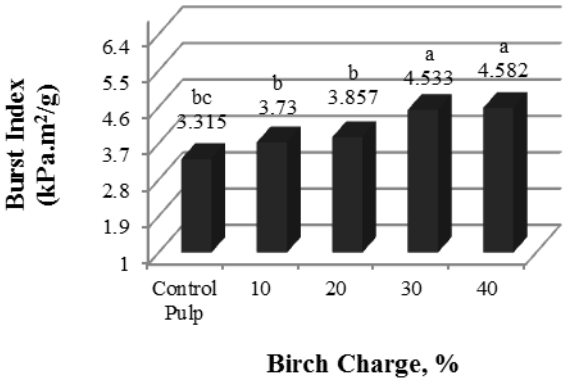

Fig.8. The effect of different charges of birch on pulp burst index.

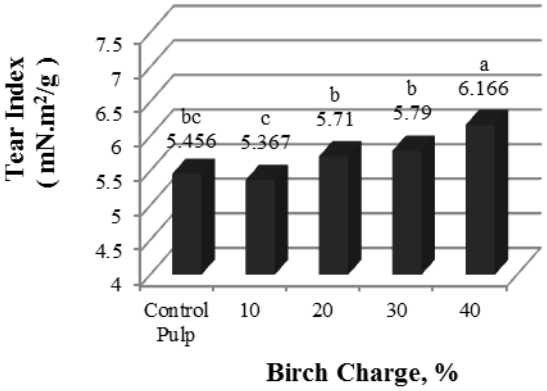

Fig.9. The effect of different charges of birch on pulp tear index.

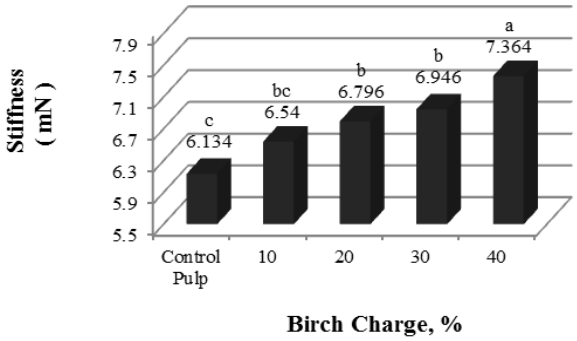

Fig.10. The effect of different charges of birch on pulp stiffness.

CONCLUSIONS

The results obtained from this research showed that partial replacement of birch wood up to 40 % in MWPI wood furnish to produce CMP pulp resulted in a better fiber length distribution, higher average fiber length, and lower fine. As a result, there were higher strength properties at a confidence level of 99%. Birch wood has a lower diameter, thinner cell wall, and higher average fiber length compared to hornbeam and beach fibers. As a result, its fibrillation is improved due to more flexibility and collapsibility, which lead to higher strength properties such as tensile, breaking length, and burst and tensile stiffness. In addition, CMP pulps containing different percentages of birch fibers resulted in papers with higher tear strength because birch pulp had higher average fiber length and lower fines, compared to hornbeam and beech in the control MWPI CMP pulp.

ACKNOWLEDGMENTS

The authors are grateful for the support of the laboratory of Wood and Paper Technology in Gorgan University of Agricultural Sciences and Natural Resources in Iran and the Research Center and Paper Testing Laboratory in Mazandaran Wood and Paper Industry (MWPI).

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Article Submitted: December 19, 2011; Peer review completed: February 06, 2012; Revised version received and accepted: May 12, 2012; Published: June 19, 2012.