African Journal of Biotechnology Vol. 10(48), pp. 9812-9816, 29 August, 2011
Available online at http://www.academicjournals.org/AJB
DOI: 10.5897/AJB11.504
ISSN 1684–5315 © 2011 Academic Journals

Full Length Research Paper

Comparison of various pulping characteristic of *Fraxinus angustifolia* Vahl. wood

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Accepted 6 June, 2011

This study was carried out in order to investigate the suitability of ash (*Fraxinus angustifolia* Vahl.), a native tree (species) in Turkey, for pulp and paper making. Four pulping methods, which included NSSC, cold soda, kraft and kraft + anthraquinone pulping processes, were used for this study. The test materials were supplied from two different stands found in Istanbul Bahcekoy region. When ash wood samples as ash 1 and ash 2 chemical contents were analyzed, the chemical components of ash 1 were higher than that of ash 2. Pulps and handsheets were obtained from ash 1 and were suitable for use in papermaking. These pulps were obtained by NSSC (neutral sulfite semi chemical pulping), cold soda, kraft and kraft + anthraquinone processes. Handsheets made from different pulping methods were compared with each other for strength and optical properties. Strength properties were found to be higher for kraft and kraft + anthraquinone processes, while optical properties were found to be higher for cold soda and NSSC processes.

Key words: Ash, *Fraxinus angustifolia* Vahl., NSSC, cold soda, kraft, kraft + anthraquinone.

INTRODUCTION

There is an increasing demand for paper and paperboard and their converted products in the pulp and paper industry. To meet this demand, it is important to investigate wood species, growing in Turkey's ecological conditions and which are still available as sustainable and alternative pulp and paper raw material supplies.

From approximately 20 million hectare, the woody area of Turkey contains 9 million hectare hardwood and 11 million hectare softwood. From the total 3.2 million hectare hardwood, small woods consist of 1.7 million small woods that are normal and 1.5 million destroyed small woods (Anonim, 2001; Cicek et al., 2005). The interest of hardwood areas are increasing in the world day to day, and as such, researches for hardwood areas should be increased as well. The important type of narrow-leaved ash, which is the widest woody area, is found in Turkey. Ash is the fastest-growing indigenous species except poplar and alder (Cicek et al., 2005).

Therefore in this study, ash (*Fraxinus angustifolia* Vahl.) was examined with various pulping methods [NSSC (neutral sulfite semi chemical pulping), cold soda, kraft and kraft+AQ (kraft + antraquinone) pulping methods] to know if it would be suitable for pulp and paper production as a quality and high yield raw material.

MATERIALS AND METHODS

Ash trees were supplied by the Forest Faculty of Istanbul (Campus and investigation and application forest), Turkey. The ash trees comprised ash 1 (62 to 64 years old and 29 to 31 cm diameter) and ash 2 (33 to 36 years old and 18 to 24 cm diameter), respectively. The ash trees were studied also, in order to compare this research with Atik (1995, 2001), NSSC, cold soda, kraft and kraft + AQ pulping methods of from trembling aspen (Table 8). Some characteristics of the sample trees are given in Tables 1 and 2. As seen in Tables 1 and 2, ash 1 was older and had larger diameter than ash 2. So, this sample was selected for the pulping methods. Two trees were selected according to TAPPI 1153-65. Three sample discs, with 20 cm thickness, were taken from each tree. When the wood samples were prepared, the barks were first removed and the discs were ground into flour in the Wiley mill according to the TAPPI os-75 standard for chemical analysis. Elimination procedure was carried out by a shaking sieve, taking the parts which pass through the 40 mesh and the remaining parts which pass through the 100 mesh, and placing them in glass jars to obtain equilibrium moisture. After determination of moisture by the use of TAPPI standards, the chemical analyses of sample woods were carried out according to the TAPPI standards given as follows (Anonymous, 1992):

Ash: TAPPI T 211 om-85; 1% NaOH solubility: TAPPI T 212 om-85; hot water solubility: TAPPI T 207 om-85; ethanol-benzene solubility: TAPPI T 204 om-88; holocellulose; Wise and John, (1952); alpha

Table 1. NSSC pulping of ash 1.

Parameter	Value
Na_2SO_3 (g/l)	50
Na_2CO_3 (g/l)	10
Liquor to wood ratio	1/5
White liquor pH	10.80
Black liquor pH	8.5
Time preheat (min)	30
Time to impregnation temperature (min)	45
Time at impregnation temperature (min)	60
Time from impregnation temperature to Max Temperature (min)	35
Time at max temperature (min)	60
Time of total pulping (min)	230
Rate of black liquor (%)	40
Impregnation temperature (°C)	120
Maximum temperature (T_{max}) (°C)	165 to 170
Maximum impregnation pressure (bar)	4.5
Max pressure (bar)	11

Table 2. Cold soda pulping of ash 1.

Parameter	Value
NaOH (g/l)	40
Liquor to wood ratio	1/5
White liquor pH	12.36
Black liquor pH	12,40
Time to max temperature (min)	90
Time at max temperature (min)	120
Time of total pulping (min)	210
Rate of black liquor (%)	40
Maximum pressure at max temperature (bar)	11
Maximum temperature (T_{max}) °C	170
Maximum pressure bar	11

cellulose: Wise et al., (1946); lignin: Runkel (1951); pentosan: Bethge (1964).

The stems (including nodes and internodes) were disintegrated up to the approximate size of industrial chips, whose length is 1 to 2 cm, thickness is 1.5 to 4 mm and width is about 1 cm depending on the stem's wall thickness. Chipped samples were screened and classified according to the chip dimension for digestion in order to provide homogeneity. The chips were prepared with four variety pulping methods (Cold soda, NSSC, kraft and kraft + AQ process) in the rotary laboratory digester. The principal parameters of each pulping process are listed in Tables 1, 2 and 3. However, the conditions for each pulping experiment were chosen close to those that were normally used for hardwoods and have been applied to ash 1 without any optimization.

Laundrie and Berbee (1972) found that the entire chips of the 3 year-old hybrid poplar required 14.2% effective alkali, while the debarked stem wood chips consumed only 12.5% effective alkali. To obtain kraft pulps, with a kappa number of 20 juvenile, poplar wood must frequently contain a considerable amount of tension wood rich in cellulose and low in lignin. Therefore, the pulping conditions are shown in Table 3. Handsheets obtained from unbleached pulps were tested by TAPPI standards methods and ISO given as follows (Anonymous, 1992):

Determination of drainability: ISO-5267-1; preparation of laboratory sheets: ISO/DIS 5269-2; standard conditioning: TAPPI T402 om-88; determination of grammage: ISO/DIS 536; tensile resistance of paper: TAPPI T 494; tearing resistance of paper: TAPPI T414 om-88; determination of opacity: ISO/DIS 2471; ISO brightness: ISO/DIS 2470; bursting strength of paper: TAPPI T403 om-91.

RESULTS AND DISCUSSION

The chemical components of ash wood specimens are given in Table 4. As it is seen in Table 4, the mean ethanol-benzene solubility was 8.08 and 4.90% in ash 1 and 2, respectively. The amount of ethanol-benzene solubility of ash 1 is approximately 2 times that of ash 2. It is thought that the increase in the solubility of

Table 3. Kraft pulping of ash 1.

Parameter	Kraft pulp	Kraft + AQ pulp
Sulfidity (as Na_2O) (%)	25	25
Active alkali % (on o.d wood)	17.5	17.5
Anthraquinone % (on o.d wood)	-	0.05
Liquor to wood ratio	1/5	1/5
Maximum pressure bar	10.5	10.5
Maximum temp. (T_{max}) °C	170	170
Time to preheat temp. (min)	20	20
Time at preheat (min)	60	60
Time from the preheat temperature to max temperature (min)	10	10
Time at max temperature (min)	90	90
Time of total pulping (min)	180	180
White liquor pH	11.40	11.53
Black liquor pH	10.50	11.40

Table 4. Chemical components of ash (%).

Sample	Ash	Ethanol benzene	Ethanol	Hot water	1% NaOH	Holocellulose	Lignin	Pentosan	α-Cellulose
Ash 1	0.77	8.08	3.41	11.23	27.63	87.39	25.53	18.46	59.45
Ash 2	0.44	4.90	6.17	9.50	15.49	85.69	23.19	16.03	55.43

carbohydrate of lower molecular weight, which degraded cellulose, polyoses, and in particular pentosan, can be explained by the effect of 1% NaOH solubility. In an acidic medium, $NaClO_2$ delignification increases the solubility of lignin. The determination of standard lignin (the residual lignin) in holocellulose always gives a low yield, which is calculated by the subtraction of the residual lignin that exceeds 100% together with the amount of lignin.

When Table 4 was studied, it was found that the cellular wall materials of ash 1, such as cellulose, polyoses, alpha cellulose and lignin, had higher amounts than those of ash 2. When the amount of pentosans in ash 1 and 2 was compared with each other, ash 1 had higher amounts than those of the ash 2. It was thought that the difference in ash 1 and 2 was caused by their ages, that is, ash 1 was older than ash 2. Therefore, ash 1 was suitably used in papermaking.

The results of pulping and pulp properties of ash 1 from different pulping processes are presented in Tables 5, 6 and 7. These strength and optical properties were compared with each other for conventional pulping processes. When the pulping processes of NSSC and cold soda were compared, they gave much higher yield, according to kraft and kraft + AQ pulp from ash 1 (40 and 42%), but kraft pulp almost gave the same pulp yield with kraft + AQ (Table 5). Also, the 40% kraft pulp yield of ash 1 was 14% less than that of *Trembling aspen* (Bella and Hund, 1973).

The NSSC and cold soda pulps showed much higher kappa numbers than kraft and kraft + AQ. According to the literature, kappa numbers, lower than 17, are considered a level of delignification common for bleachable grade hardwood kraft pulps (Hatton and Heijas, 1972). Therefore, the kraft and kraft + AQ pulps are suitable for bleachable pulps, even though the strength properties can be easily improved with minimal energy requirements on beating. When the same pulp freeness was compared with the revolution of beating of kraft and kraft + AQ pulps, the revolutions (rev.) of beating of kraft pulp varied from that of kraft + AQ pulp. Kraft pulp took only 1800 PFI rev. to reach a drainage resistance of °SR 45, while kraft + AQ pulp took only 1500 PFI rev. to reach a drainage resistance of about °SR 46 (Table 6).

According to Nakano and Hosoya (1981), the low alkalinity and presence of AQ were found to have a beneficial effect on carbohydrates dissolution through suppression of the reaction and alkaline hydrolysis, providing high yield and high viscosity of pulps. The difference in beating of kraft + AQ pulp was probably the result of different responses of parenchyma cells in the raw material to AQ conditions of kraft + AQ pulping than that of kraft pulp from ash 1 (Table 5). On the other hand, the pulp of cold soda was difficult to beat. It was first refined in Sprout Waldron type of refiner and later beaten by 1500 PFI rev. to reach a drainage resistance of °SR 45. At a similar manner, NSSC pulp was difficult to beat. However, it had to be processed for a second time, and it was both refined and beaten by 1000 PFI rev. to reach a drainage resistance of °SR 45 (Table 6). It was evident that kraft + AQ pulp had the fastest response on beating for all pulps from ash 1. When the values of the strength

Table 5. Characteristics of ash 1 pulps.

Pulping method	Total yield %	Kappa number	Residual lignin %	Reference
**NSSC	67	87.67	13.15	Current study
*Cold soda	56	64.87	9.73	Current study
Kraft	40	10.47	1.56	Current study
Kraft + AQ	42	9.89	1.48	Current study
*Kraft	54	18	3.05	Bella and Hund (1973)

*Trembling aspen; **refined second time.

Table 6. Physical properties of ash 1 pulps.

Method of pulping	*Cold soda	**NSSC	Kraft	Kraft + AQ
Drainage resistance ^{O}SR	45	45	45	46
PFI (rev.)	1500	1000	1800	1500
Bulk (kg/m^3)	448	429	756	627
Tear index (mNm^2/g)	3.6	2.7	6.0	6.2
Tensile index (Nm/g)	21.76	24.10	54.88	47.25
Bursting (kPam^2/ g)	0.82	1.26	3.31	2.84
Porosity (s/100ml)	1.25	0.49	7	7

*Refined first time; ** refined second time.

properties for the four conventional different pulps were compared with each other, tensile strength index of kraft pulping method had the maximal value, while the cold soda pulping method had the minimum value. When compared at the same tearing strength, bursting strength of kraft and kraft + AQ pulps (kraft similar to kraft + AQ), from ash 1 was higher than that of NSSC and soda pulps (NSSC pulp similar to cold soda pulp) (Table 6). It was clearly shown that kraft + AQ and kraft pulping methods of the strength properties were higher than that of soda and NSSC pulping methods. Also, these values are comparable with those of conventional pulps from trembling aspen (Table 8). Although the tearing strength of NSSC and cold soda from ash 1 were higher than that of NSSC with 92 and 87%, cold soda pulp from the trembling aspen and kraft pulp from ash 1 were higher than kraft pulp from trembling aspen with 38%. Thus, the tensile strength of NSSC, cold soda and kraft pulps from ash 1 were lower than the conventional pulp (NSSC, cold soda and kraft) from trembling aspen by 92, 87 and 38%, respectively. Also, the bursting strength of cold soda, NSSC and kraft from ash 1 were lower than that of the trembling aspen by 75.6, 54.8 and 16.3%, respectively.

When the values of porosity properties of the handsheet of the four various pulping methods were compared with each other, kraft and kraft + AQ pulping method gave the highest porosity value, while NSSC pulping method gave the lowest value (Table 7). When the values of the optical properties of the conventional pulps were compared with each other, brightness of cold soda pulping method had the maximal value, while kraft + AQ pulping method had the minimum value (Table 7). However, opacity of NSSC pulping method gave the maximal value, while cold soda pulping method gave the minimum value (Table 7). Also, these values were compared with those of conventional pulps from trembling aspen (Table 8). Although the brightness of NSSC pulp from ash 1 was higher, the cold soda from ash 1 was lower than that from trembling aspen (Table 8).

According to the CIELAB system, the color of the paper from pulp is defined in Equation 1 as follows: L (measure of luminance), a (redness to greenness) and b (yellowness to blueness) (Vaarasalo, 1999).

$$\begin{array}{llll} L = 0 & \text{Black} & L = 100 & \text{White} \\ a > 0 & \text{Red} & a < 0 & \text{Green} \\ b > 0 & \text{Yellow} & b < 0 & \text{Blue} \end{array} \quad [1]$$

According to the test results in Table 7 and in Equation 1, the color of the handsheet from kraft pulp is dark yellow, which contained mixed green, but the color of the handsheet from soda pulp is almost yellow. The dark yellow color can be explained as a characteristic of the kraft pulp's color. Also, the values of yellowness given in Table 6 supported these expressions. In addition, the opacity values of kraft pulp had negative relationship with values of yellowness.

Conclusion

The conventional delignification of ash 1 showed the

Table 7. Optical properties of ash 1 pulps.

Parameter	NSSC	Cold soda	Kraft	Kraft + AQ
Brightness (%ISO)	32.77	45.16	32.61	29.77
L	69.13	84.66	69.35	66.72
A	9.50	0.40	5.31	6.13
B	9.35	22.09	10.01	9.54
Yellowness	18.64	33.27	19.51	19.29
Opacity	100.0	91.74	99.14	99.53

Table 8. Strength and optical properties of pulps.

Parameter	NSSC** trembling aspen	Cold soda* trembling aspen	Kraft** trembling aspen	NSSC ash 1	Soda ash 1	Kraft ash 1
Tear index (mN.m^2/g)	0.46	0.67	0.88	3.68	3.60	6.00
Tensile index (N.m/g)	46.35	40.86	75.93	24.10	21.76	54.88
Bursting index (kPa.m^2/g)	1.95	1.44	3.85	1.26	0.82	3.31
Brightness (%)	30.33	47.90	-	32.77	45.16	32.61
Opacity (%)	98.24	85.54	-	100	91.74	99.14

*Atik (1995); **Atik (2001).

potential applicability of conventional pulping technologies for this hardwood for production of high quality wood fibres and papermaking.

Bleachable grade pulps (kraft and kraft + AQ) with low content of residual lignin, comparable with pulps of ash 1, were produced by NSSC and cold soda. From the results of the study, it was found that the strength properties of kraft and kraft + AQ were higher than those of the NSSC and cold soda process, while the optical properties were lower than those of the NSSC and cold soda process.

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