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Effect of Bleaching Condition on Optical and the Physical Properties During the Bleaching of Poplar Organosolv Pulps with Two-stage Hydrogen Peroxide

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Abstract: Nine different two-stage bleaching trials were carried out to determine the effect of bleaching conditions on the optical and physical properties of pulps during the bleaching of poplar wood organosolv pulp with hydrogen peroxide. The results indicated that optimum poplar organosolv pulps bleaching conditions were as below; Hydrogen peroxide (H_2O_2) ratio on oven dry (o.d) pulp: 2-4%, alkali (NaOH) charge on o.d pulp: 1.5-3%, Na_2SiO_3 ratio on o.d pulp: 3%, $MgSO_4$ ratio on o.d pulp: 0.5%, EDTA ratio on o.d pulp: 0.5%, reaction temperature: 70°C, reaction time: 70 min and concentration: 16%. Thus, optical and physical properties of bleached poplar organosolv pulps with two-stage H_2O_2 were found to be higher than those of unbleached pulps.

Key words: Bleaching, poplar, organosolv pulp, hydrogen peroxide, two-stage

INTRODUCTION

Enhanced poplars, or super trees have been widely planted all over the world. The main feature of these trees is that they grow fast, as much as three metres in height per year, or 20 and 50 cubic m ha^{-1} in fertile coastal soils in Turkey[1]. This kind of fast-growing fibre source is extremely important for pulp and pulp bleaching mills. The organosolv process uses equal parts denatured ethanol and water to create acidic liquor and produces a higher- pulp yield compared with traditional kraft and other chemical pulps.

Poplars provide a bright, white wood that requires less hydrogen peroxide for bleaching and they have been thought as a way to take some of the pressure off those species that have been traditionally used for pulp. It is predicted that the major virgin raw material for pulp and paper will continue to be wood and poplar wood fibres will have a much greater role than other wood fibres.

The pulp and pulp bleaching industry is a large and growing portion of the world's economy. Pulp and paper production from poplar wood has increased globally and will continue to increase in the near future. However, the industry is very capital-intensive with small profit margins, which tends to limit experimentation, development and incorporation of new technologies into the mills. The pulp-paper and bleaching industries are also under constant pressure to reduce and modify environmental emissions to air and water[2].

Today, bleaching technology is possibly developing faster than ever. Hydrogen peroxide is one of the most important bleaching chemicals. It is a strong oxidising agent, which has variety of different applications in all kinds of pulp produced in the pulp and paper industry. On of the biggest advantage of hydrogen peroxide is that it is environmentally friendly throughout its whole life cycle, from the raw materials used in production to the disposal of the product[3].

In chemical pulp bleaching, hydrogen peroxide is most important future bleaching chemical. It replaces chlorine and chlorine dioxide. Bleaching of chemical pulp has been dominant application of hydrogen peroxide. Hydrogen peroxide bleaching improves pulp quality making it possible to use more chemical pulp in the higher grades of paper[4].

The perhydroxyl anion (HOO^-) is generally accepted as being the principal active agent in peroxide bleaching. This anion is a strong nucleophile which, during bleaching, converts electron-rich chromophores typified by α-β-unsaturated aldehydes and ketones and phenolic ring-conjugated ethylenic or carbonyl groups to their non-chromophoric counterparts. The reactions of lignin

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with peroxide are not reversible and lead to the permanent removal of most of the chromophoric groups present in the lignin molecule[5].

In the bleaching of beech NSSC pulps with H_2O_2, brightness increased from 39 to 71.6% elrepho and kappa number decreased from 89.7 to 39.4[6]. In a study conducted by Allison[7] on pine TMP and CMP bleaching, brightness of TMP rises to 76% ISO and that of CTMP to 78.5% ISO under the conditions of 3% sodium silicate, 20% concentration, 60°C temperature, 120 min reaction time and 4% H_2O_2. Usta *et al.*[3] indicated that when CTMP having 47% elrepho brightness was bleached under the conditions of 3.5% H_2O_2, 3% NaOH, 3% Na_2SiO_3, 0.5% $MgSO_4$, 0.5% EDTA and 70°C temperature and 100 min reaction time, brightness value was 74.20% elrepho and yellowness decreased from 321 to 193.8‰ elrepho.

Poplar ethanol-water (EW) pulp showed good response to oxygen-delignification at medium consistency. Kappa number of oxygen-delignificated pulps was determined to be 17 and it was possible to reach 62% delignification level without serious viscosity lost[8].

In this study, Nine trials were performed for two-stage bleaching with using H_2O_2 (PP) as bleaching chemical agent. Results were expressed as optical (brightness, yellowness and opacity) and physical (breaking length, tear and burst index) properties of the pulps.

MATERIALS AND METHODS

Poplar organosolv pulps used in this study were produced in the laboratory conditions. The yield, brightness and yellowness of these pulps were 42%, 27% elrepho, 471‰ elrepho, respectively.

In order to determine optimum two stage hydrogen peroxide bleaching conditions of poplar pulp. A total of 9 with two-stage bleaching experiments were carried out. In these trials, different parameters of bleaching were varied at the level indicated below:

H_2O_2	:	2.0, 3.0 and 4.0% (first stage)
NaOH	:	1.50, 2.25 and 3.0% (first stage)
H_2O_2	:	2.0, 3.0 and 4.0% (second stage)
NaOH	:	1.50, 2.25 and 3.0% (second stage)
Reaction time	:	60, 70 and 80 min

On the other hand, ratio of Na_2SiO_3 $MgSO_4$ and EDTA, reaction temperature and concentration were kept constant at the levels 3, 0.5, 0.5%, 70°C and 16%, respectively. In all experiments $NaOH/H_2O_2$ ratio were 0.75.

After preparing bleaching liquors of indicated quantities pulps were placed in polyethylene bags. Then, the mixtures were put in a circulation water bath and the temperature was controlled by a thermostat. At the end of the bleaching time, liquor samples were taken to determine final pH and residuals according to CPPA standard J.16P[9]. The pulps were diluted to 1% consistency and then neutralized with sodium metabisulfite in order to decompose the residual H_2O_2 and stabilize the brightness. Then bleached pulp was pressed up to 15-20% dryness. Later on, moisture content of pulps regulated to 20-25% and placed in polyethylene bags and moisture content determinations were realised. All pulps were beaten in a Valley Beater to 35±2 and 50±2 SR° freeness levels and handsheets were made on a Rapid Kothen machine. In 35±2 SR° optical and in 50±2 SR° physical properties of handsheets were performed according to TAPPI test methods[10], but viscosity values according to SCAN C 16:88[11].

RESULTS AND DISCUSSION

A total of nine bleaching trials were realised on two-stage bleaching of poplar organosolv pulps with H_2O_2. Peroxide bleaching in two successive stages allows for higher brightness gains at lower costs than single stage bleaching. The bleaching yield decreased with an increase in the number of stages (Table 1). Kappa number and pulp viscosity decreased with increased reaction time, which corresponds to other H_2O_2 pulp bleaching[12,13]. When all other conditions were kept constant, bleaching yield decreased with increasing hydrogen peroxide ratio (Table 1). For example, while bleaching yield was 94.78% with 2% peroxide, the same value was found to be 94.05% with using 4% peroxide. As can be seen in Table 1, when all other conditions were kept constant, bleaching yield decreased with increasing hydrogen peroxide ratio. For example, while bleaching yield was 95.12% with 2% peroxide, the same value was found to be 93.64% with using 4% peroxide. In these trials reaction temperature, reaction time, $MgSO_4$, EDTA, Na_2SiO_3 and concentration were constant at the levels of 70°C, 60 min, 0.5, 0.5 and 3%, respectively.

In Table 1, the brightness values of pulp bleached with H_2O_2 increased with the increasing peroxide and NaOH ratios. For instance, at the presence of 2% H_2O_2, the brightness was 58.57% elrepho, whereas, at the presence of 4% H_2O_2, the brightness was 70.15% elrepho. However, the yellowness of pulp decreased with increasing the ratio of peroxide and NaOH. As a result, poplar organosolv pulps can be easily bleached to 70.15% elrepho brightness with two-stage bleaching using H_2O_2

Table 1: Experimental design and some optical and physical properties of poplar organosolv pulps bleached with two-stages H_2O_2

Trials no.	Sequences	Chemicals	Reaction time	Reaction temperature	Concentration (%)	Black liquor pH	Bleaching yield (%)	Kappa number	Pulp viscosity ($cm^3\ g^{-1}$)
1	PP	2% H_2O_2, 1.5% NaOH	60	70	16	9.20	95.12	17.1	1150
		2% H_2O_2, 1.5% NaOH	60	70	16	10.65			
2	PP	3% H_2O_2, 2.25% NaOH	60	70	16	9.10	94.35	15.5	1090
		3% H_2O_2, 2.25% NaOH	60	70	16	10.40			
3	PP	4% H_2O_2, 3% NaOH	60	70	16	9.00	93.64	13.9	1063
		4% H_2O_2, 3% NaOH	60	70	16	10.25			
4	PP	2% H_2O_2, 1.5% NaOH	70	70	16	9.00	94.63	16.8	1115
		2% H_2O_2, 1.5% NaOH	70	70	16	10.10			
5	PP	3% H_2O_2, 2.25% NaOH	70	70	16	8.95	93.41	15.1	1070
		3% H_2O_2, 2.25% NaOH	70	70	16	10.00			
6	PP	4% H_2O_2, 3% NaOH	70	70	16	8.90	92.27	13.4	1057
		4% H_2O_2, 3% NaOH	70	70	16	9.95			
7	PP	2% H_2O_2, 1.5% NaOH	80	70	16	8.98	93.27	16.1	1095
		2% H_2O_2, 1.5% NaOH	80	70	16	9.94			
8	PP	3% H_2O_2, 2.25% NaOH	80	70	16	8.93	92.70	14.3	1055
		3% H_2O_2, 2.25% NaOH	80	70	16	9.90			
9	PP	4% H_2O_2, 3% NaOH	80	70	16	8.90	91.46	12.9	1034
		4% H_2O_2, 3% NaOH	80	70	16	9.85			

Trials no.	Sequences	Chemicals	Reaction time	Brightness (% elrepho)	Yellowness (‰ elrepho)	Opacity (%)	Breaking length (km)	Tear index ($mN\ m^2\ g^{-1}$)	Burst index ($kPa\ m^2\ g^{-1}$)
1	PP	2% H_2O_2, 1.5% NaOH	60	56.18	283.17	88.60	6.17	6.56	4.04
		2% H_2O_2, 1.5% NaOH	60						
2	PP	3% H_2O_2, 2.25% NaOH	60	64.87	250.61	92.93	6.35	6.67	4.23
		3% H_2O_2, 2.25% NaOH	60						
3	PP	4% H_2O_2, 3% NaOH	60	68.09	214.12	86.71	6.42	6.71	4.41
		4% H_2O_2, 3% NaOH	60						
4	PP	2% H_2O_2, 1.5% NaOH	70	58.57	272.10	87.25	6.25	6.65	4.20
		2% H_2O_2, 1.5% NaOH	70						
5	PP	3% H_2O_2, 2.25% NaOH	70	66.83	235.41	91.81	6.41	6.70	4.37
		3% H_2O_2, 2.25% NaOH	70						
6	PP	4% H_2O_2, 3% NaOH	70	70.15	206.73	85.10	6.50	6.78	4.50
		4% H_2O_2, 3% NaOH	70						
7	PP	2% H_2O_2, 1.5% NaOH	80	57.51	278.43	86.55	6.37	6.77	4.35
		2% H_2O_2, 1.5% NaOH	80						
8	PP	3% H_2O_2, 2.25% NaOH	80	65.90	247.17	89.27	6.46	6.85	4.47
		3% H_2O_2, 2.25% NaOH	80						
9	PP	4% H_2O_2, 3% NaOH	80	69.01	211.33	83.37	6.61	6.91	4.63
		4% H_2O_2, 3% NaOH	80						

Note: For all trials EDTA, $MgSo_4$ and $NaSiO_3$ were taken constant as 0.5, 0.5 and 3%, respectively

as the chemical agent. At the bleaching of poplar organosolv pulps brightness of pulp increased from 27% to 70.15% elrepho and yellowness of pulp with bleaching decreased from 471 to 206.73‰ elrepho.

Increasing reaction time to 60, 70 and 80 min, while keeping other bleaching conditions constant, slightly decreased pulp opacity. Consequently, all the optical properties of pulp obtained with H_2O_2 bleaching increased with the increasing H_2O_2 ratio.

The effect of reaction time and peroxide rate on strength properties of handsheets are illustrated in Table 1. The bleached poplar organosolv pulps were beaten to 50±2 SR° freeness levels. A gradual increase of time resulted in gradual increase in breaking length from 6.17 to 6.25 and to 6.37 km.

Generally, breaking length increases with increasing the of H_2O_2 rate[12,13]. In Table 1 (trials no: 4, 5 and 6), at 2, 3 and 4% H_2O_2 rate, tear and burst index were 6.65, 6.70, 6.78 $mN\ m^2\ g^{-1}$ and 4.20, 4.37, 4.50 $kPa\ m^2\ g^{-1}$, respectively. In addition, increasing reaction time from 60 to 70 and to 80 min and peroxide rate from 2 to 3 and to 4% caused increase in breaking length, tear and burst index.

According to the results, the bleaching of poplar organosolv pulp with two-stage bleaching sequences offers the following advantages:

- Printing and aspect properties of bleached poplar organosolv pulp are improved with brightness increase and yellowness decrease.
- Increased production at fixed brightness.
- The aging tendency of bleaching poplar organosolv pulp decreases with single or multistage sequences using H_2O_2.
- Physical and optical properties were improved during H_2O_2 bleaching.

As a result of all these advantages, poplar wood organosolv pulps bleached by two-stage hydrogen peroxide can be used in the production of newsprint and high-quality printing and writing papers due to its very good paper formation and surface smoothness. It can also be used in the production of tissue papers by adding sulphate or sulphite pulps and in the production of food board used in packing of liquid and food material by mixing with the bleached sulphite or sulphate pulp.

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