Characterisation of Birch (*Betula papyrifera* Marsh.*)* wood discoloration during drying

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ABSTRACT

White birch (*Betula papyrifera* Marsh.) wood is highly appreciated for its clear and uniform coloration. Conversely, discoloration can cause important financial losses due to depreciation of high valued products. However, there is a lack of an understanding of the discoloration development. To understand the origin of white birch wood discoloration during drying, green-wood boards were kiln dried using a conventional program. A complex experimental design was applied in order to understand the chemical change of the extractives onto the discoloration. Both color measurements and chemical characterisation of wood before, during and after drying have been performed. In addition, the boards were examined at three levels of thickness to determine if the chemical changes took place at different locations chosen for sampling. Preliminary results show important variations in phenolic extractives through the board, especially for the condensed tannins (proanthocyanidins) which are most likely participating the reactions causing the birch wood discoloration.

Keywords: *Betula papyrifera*, discoloration, drying, extractives, Paper birch, phenolics, proanthocyanidins.

INTRODUCTION

Paper birch (*Betula papyrifera* Marsh.) is an important species for the Canadian forest industry considering its availability throughout the country (Duchesne and Rancourt 2005; Giroud 2005, 2008). Its homogenous and light colored wood is much appreciated for appearance products. Some wood secondary metabolites, called extractives, have been proposed to be responsible for the discoloration occurring during birch wood drying. Paper birch is mostly conventionally dried at temperatures from 40 to 80°C (Kärki and Möttönen 2004; Möttönen 2005). The drying schedules are usually modified in order to avoid wood discoloration (Stenudd 2002), by using low temperatures which is on the other hand causing the production issues. But even with these modifications, change of wood color occurred (Luostarinen *et al.* 2002). The downgrading of discolored wood causes big financial looses to the industry (Levitin 1970, Luostarinen and Verkasalo 2000, McCurdy et al. 2001).

Many parameters have been studied to find an explanation for wood discoloration. In hardwoods discoloration is mainly due to the occurence of specific phenolics such as proanthocyanidins (PAs) also known as condensed tannins (Luostarinen and Möttönen 2004a; Rappold and Smith 2004). They become colored following polymerisation and oxidation reactions. Luostarinen and Möttönen determined a correlation between proanthocyanidins concentration and changes in color of birch wood during storage and drying (Luostarinen and Möttönen 2004b).

Many studies have associated the presence and changes of these phenolics to the development of discoloration subsequent to storage and drying (Burtin et al. 2000; Sundqvist 2002; Koch et al. 2003; Koch 2004; Luostarinen and Möttönen 2004a,b; Mayer et al. 2006). However most of the reactions involved on wood discoloration remain still not well known (Luostarinen et al. 2002; Hiltunen et al. 2004).
Wood discoloration in paper birch is a heterogeneous process. Usually the core of the board is discolored while the surface is keeping its clear coloration (Luostarinen and Luostarinen 2001; Luostarinen et al. 2002). However a migration of monosaccharide has also been determined (Luostarinen and Luostarinen 2001; Kärki and Möttönen 2004; Luostarinen and Möttönen 2004a,b) which could cause coloration problems (or apprearance change) close to the surface (Möttönen 2005).

No standard method is used to measure wood color in the industry. Operators are generally trained to visually classify the boards in few categories during hours, resulting in an inaccurate and limited practice. Some techniques have been proposed to avoid these problems using color measure devices like spectrophotometers and on-line scanners. Spectrophotometers, also called colorimeters, are generally used in the laboratory (off-line) to measure a specific zone of the board. Advanced and expensive scan systems are used to perform color measurements and classification decisions on the production line. Usually this approach requires a higher investment but gives quicker and more precise information.

The aim of this research was to determine the effect of drying on wood discoloration depending on two factors: moisture content and distance from the board surface. Also to identify the phenolic extractive compounds responsible for wood discoloration and to propose the reactions which are causing the introduction of chromophores.

MATERIALS AND METHODS

Wood drying

Freshly cut paper birch boards (2.4 m. long, random width) were quickly transported from a sawmill to Laval University (Québec, Canada). The boards were stored at -7°C in order to keep the green condition until their processing. The 2.4 m long boards were cut into 30 x 100 x 600 mm. boards keeping the couples of neighbours together for color/chemical-composition comparison. A series of three dryings were performed on 30 boards, in a conditioning chamber with accurately controlled temperature and relative humidity based on the wood moisture content (Table 1). Three different board depths were chosen to study both color and chemical composition: the surface, the center and an intermediate zone.

Table 1. Drying schedule based on moisture content.

Moisture Content %	Temperature [°C]	Relative Humidity [%]
>40%	60.0	82.2
40%	60.0	75.3
35%	60.0	64.7
30%	65.5	49.0
25%	71.1	31.6
20%	76.7	24.1
15%	82.2	24.1
Conditionning	82.2	84.0

The three drying charges were composed of 5 groups of 6 boards each from which 4 groups corresponding to moisture contents of 40-30%, 30-20%, 20-10% and final were used for color/chemical determinations and the last one was used as control to follow the change of wood moisture content during drying. Each group was replicated 3 times par drying. A sixth group was kept outside for green conditions. Each group was composed of 3 boards for color determinations and each board's couple for chemical determinations (Fig. 1). During drying these board groups were taken out of the chamber at different moisture contents (Fig. 1) to be analyzed. They were replaced by already dried boards to fill the vacant space.

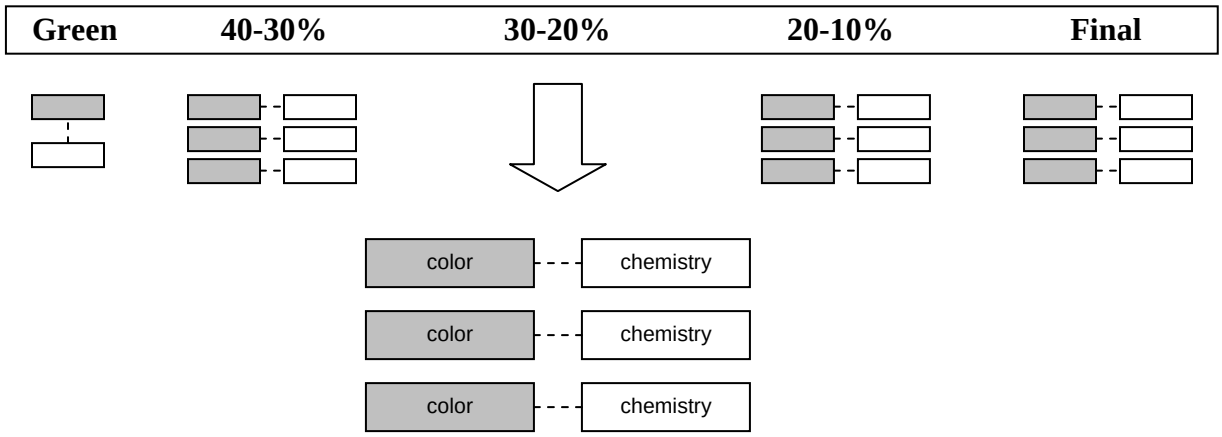

Fig. 1. Wood sampling from each drying charge excluding the 6 boards used as control for the moisture content determination during drying.

Determination of total extractives content

Total extractives content was obtained after toluene-ethanol and boiling water extractions. Five grams of wood particles were first extracted in a Soxhlet system with a toluene-ethanol (30/70, v/v) solvent for 6 hours. The extract was then concentrated in a rotary evaporator and dried for 12 hours to obtain the mass of extractives. The extracted wood was dried at room temperature for 24 hours. Two grams of extracted wood were then extracted with hot water under reflux for 3 hours. The extract was then filtered, the extracted wood washed with boiling water and oven-dried at 102 °C for 24 hours. The extractives content was expressed as a percentage of the oven-dry mass of the wood samples.

Determination of soluble phenolics

Wood particles were mixed with methanol/water (80/20, v/v) using 10 ml of solvent per gram of wood. The mixture was shaken at room conditions for 24 hours. The extract was then filtered and stored in cold conditions until the phenol content was measured according to the colorimetric method of Folin-Ciocalteau (Scalbert et al. 1989). The extract was diluted 1:2 using the same solvent to obtain an absorbance value lower than 1.0 according to the Lambert Beer Law. A volume of 2.5 ml of the Folin Ciocalteau reagent and 2 ml of sodium carbonate (75 g/l) were added to each 0.5 ml of extract aliquot. After vortex agitation, the tubes were disposed in a thermostatic bath at 50°C for 5 min. The absorbance was measured at 760 nm with a Varian Cary 50 UV/VIS spectrophotometer. Catechin was used as standard and the equation of the curve for soluble phenolics determination was:

$$y = 0.0091x + 0.0242 \qquad (r^2 = 0.9984)$$

Determination of soluble and insoluble proanthocyanidins

The amount of soluble proanthocyanidins was estimated by the colorimetric method in acid alcoholic medium. A volume of 6 ml of acid butanol (n-butanol/concentrated HCl, 95/5 v/v) and 0.2 ml of iron reagent (2% ferric ammonium sulphate in N HCl) were

added to each 1 ml of extract aliquot. The tubes were agitated using a vortex and then disposed in a thermostatic bath at 95°C for 50 minutes. The absorbance was read at 550 nm in a Varian Cary 50 UV/VIS spectrophotometer. Purified tannin of paper birch was used as standard and the equation of the curve for proanthocyanidins determination was:

$$y = 0.0041x + 0.0041 \qquad (r^2 = 0.9964)$$

In the case of insoluble proanthocyanidins, the reagents were added to 100 mg of wood particles already extracted in 1 ml of methanol/water (Lavisci et al. 1991).

Wood color measurement

A new scanning technique was used to measure the color of wood. This technique allowed us to measure the whole surface of each board. The color space was L*a*b* where L* stands for lightness from 0 (black) to 100 (white). The chromatic coordinates a* and b* stand for green/red (-a/+a) and blue/yellow (-b/+b), respectively. A big format scanner Epson Expression 1640XL scanner was used to acquire the images. A Macbeth color chart was used to correct the colors and calibrate the images. The software "treatment", developed by the Québec Center for Industrial Research CRIQ, was used for color determinations.

RESULTS AND DISCUSSION

Preliminary results have shown an important variation in phenolic extractives (Fig. 2), especially for the soluble proanthocyanidins (condensed tannins) which are most likely participating the reactions causing birch discoloration (Luostarinen and Möttönen 2004a; Möttönen 2005).

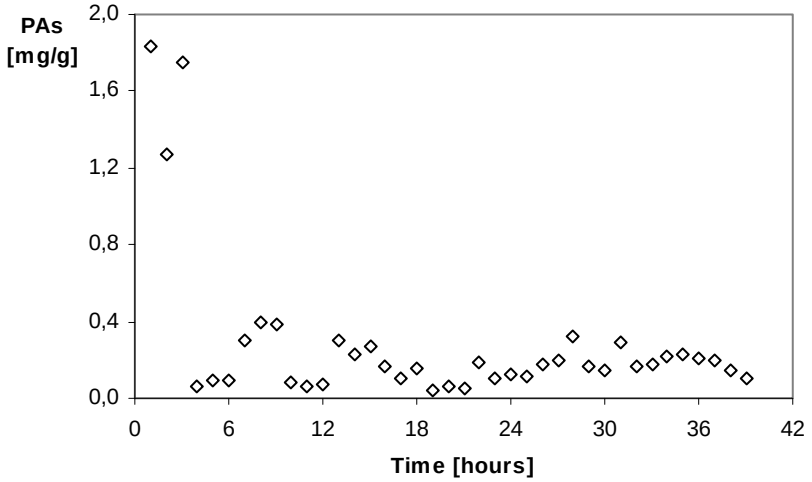

Fig. 2. Concentration of soluble proanthocyanidins (sPAs) by drying time.

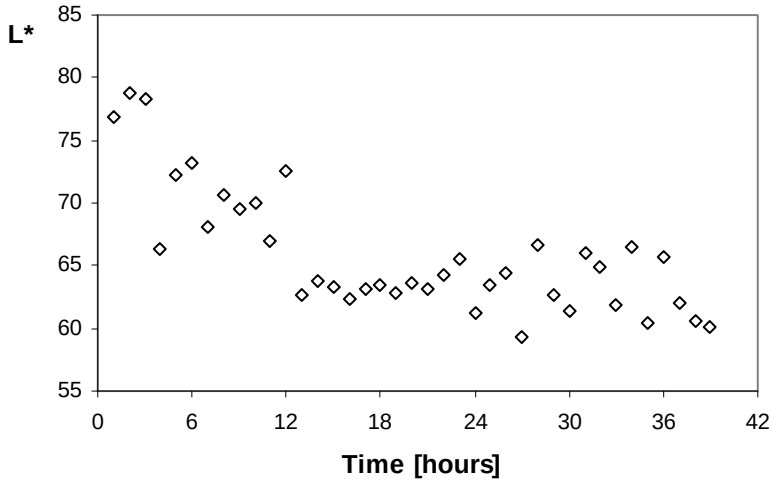

Fig. 3. Lightness (L*) coordinate from Lab color space during drying.

The relationship between concentration of proanthocyanidins and wood lightness as can be seen from the Figures 2 and 3 seem to confirm the importance of condensed tannins in birch discoloration (Luostarinen and Möttönen 2004b) as the wood became darker when the concentration of soluble tannins decreased.

Once the project will be complete, this information could be useful for the control of wood discoloration: at the silvicultural level by controlling the biosynthesis of discoloration precursors and at the processing stage, by modifying the drying schedule at the right time in order to reduce the discoloration.

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