Relationship between Color Modification and Dimensional Stability Improvement of a Thermally Treated OSB

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Abstract

A very promising method to improve the dimensional stability of oriented strand boards (OSB) has been studied in Brazil since 2001. According to this method, the board is thermally treated at mild conditions using a hot-press. The results obtained until this moment show an improvement of the dimensional stability, without adverse effect on mechanical properties, but the colour is modified. This paper aims to evaluate the relationship between colour modifications and the improvement of the dimensional stability of the thermally treated OSB. Samples from 36 commercial OSB were thermally treated according to two levels of temperature (190 and 220ºC) and three heating times (12, 16 and 20 min) using a single opening hot-press. The colour of the treated samples was measured before and after the thermal treatment according to the CIE L*a*b* system by using the Datacolor Microflash D200 spectrophotometer. The variables lightness (L^*), redness (a^*), blueness (b^*), hue (h) and the chromaticity (C) were obtained. The colour (ΔE^*) and chromaticity difference (ΔC^*) were also calculated. The samples were tested according to ASTM D1037 to evaluate thickness swelling (TS) and water absorption (WA) after 24 hours of water soaking. Permanent thickness swelling (PTS) and equilibrium moisture content (EMC) were also determined. Strong relationships between colorimetric variables and properties related to dimensional stability were found. As the board became darker, L^* was decreased, and the anti-shrink efficiency (ASE) was higher. The variable related to color modification (ΔE^*) was found to have an inverse relationship with PTS and EMC. Several linear regression models could be generated to explain these relationships. Finally, it could be concluded that colour measurement is a suitable method to predict the improvement of the OSB dimensional stability imparted by the proposed thermal post-treatment.

Key words: thermal treatment, colour changing, dimensional stability, OSB.

Introduction

Plywood and OSB can be considered similar in conception both being wood composites, because the principle of the cross lamination is present. This improves the dimensional stability of the panel and it reduces, partly, the anisotropy relative to the moisture and the mechanical efforts, that it are so common to the solid wood. However, the main drawback of OSB is the low dimensional stability in comparison with plywood. Besides the inherent wood hygroscopicity, the stress imposed during hot-pressing plays an important role in the OSB dimensional instability.

The efforts to improve the dimensional stability of reconstituted panels are focused on two main factors: the reduction of the hygroscopicity and the release of the mat stress imposed during the hot-pressing. In this context several methods have been evaluated: furnish thermal treatments (Paul et al. 2006), furnish chemical modification (Okino et al. 2004), prolonged hot-pressing (Winandy and Krzysik 2007) and post-treatment of the consolidated panel (Suchsland and Xu 1991).

A kind of thermal post-treatment method has been studied in Brazil since 2001. In this method, consolidated OSB is thermally treated using a hot-press; the heat transference is provided by a slight contact pressure between plates of press and the surface of the board. This way, the release of the compression stresses is achieved because the board is heated up to the temperature where the wood matrix loses its stiffness, so they can be rearranged at a low level. It is the glass transition temperature (Tg).

The method imparts a temporary loss of stiffness of the board, just enough to release those stresses. On the other hand, as the board is heated above Tg some chemical degradation happens, mainly hemicelluloses, which are the least thermally stable wood polymer. To avoid the adverse effects of thermal treatments on the mechanical properties, the process is controlled by using some conditions: fast heating (<30min), atmosphere pressure and lower moisture content (<11%).

According to the results obtained until this moment for this method, the treated boards have better dimensional stability (Okino et al. 2008, Del Menezzi and Tomaselli 2006), higher fungi resistance (Del Menezzi et al. 2008b, Okino et al. 2007), and smoother surface (Del Menezzi et al. 2008a) than the untreated OSB. After natural weathering exposure treated boards maintained their strength and stiffness at a higher level as well (Del Menezzi et al. 2008b). This improvement in performance has been obtained without any significant deleterious effect on mechanical properties (Del Menezzi et al. 2008a, Okino et al. 2007).

However, as a thermal treatment it provokes change in color, darkening the surface of the board. The change in color of heat-treated wood products has been investigated to predict the degree of the modification of the properties of the material (Brischke et al. 2007, Schnabel et al. 2007). The results have shown that is possible to use the color variables to estimate wood loss of weight imposed by the thermal treatment, which has a close relationship with the enhancement of the properties. In fact, according to Pellerin and

Ross (2002) the measurement of color can be considered a non-destructive method to evaluate the quality of wood products.

This way, the present work aimed at studying the possibility of employing color measurement to predict the dimensional stability improvement of OSB imparted by the proposed thermal post-treatment.

Materials and Methods

Thermal Treatment

Thirty-six commercial OSB boards (12.5mm; 640kg/m^3; FF-MDI adhesive) were obtained from an industrial batch and treated at two temperature levels (190 and 220^{o}C) for 12, 16 and 20 min in a laboratory single opening hot-press. Each combination of temperature-time was considered a group: T1-190ºC/12 min; T2-190/16; T3-190/20; T4-220/12; T5-220/16 and T6-220/20. The pressure (<20kPa) was applied just to assure the contact between the platens and the surface of the boards. Further information on the thermal treatment can be obtained in Del Menezzi et al. (2008a).

Dimensional Stability Properties

After the thermal treatment four samples per board were cut to determine water absorption (WA24) and thickness swelling (TS24) after 24 hours of water soaking according to the ASTM D1037. The samples measured 76x76x12.5mm^3 and were put in a conditioned room (65%; 20ºC) until reaching constant weight.

After the test, the samples were dried (103±2ºC) and the dimensions were measured again to calculate permanent thickness swelling (PTS). Equilibrium moisture content (EMC) was the percent difference between the weight before soaking and after drying. TS and EMC values of untreated (V_u) and treated (V_t) boards were employed to calculate anti-shrink efficiency (ASE) and anti-moisture efficiency (AME) of the treatment according to Equation 1.

$$ASE, AME = \left(\frac{V_u - V_t}{V_u} \right) \qquad \text{Eq. (1)}$$

Colour Measurement

The color of the boards was measured according to the CIE $L^*a^*b^*$ System using the Datacolor Microflash D200 spectrophotometer. The device was set for D65 illuminant and measurement angle of 10^o. The variable lightness (L^*) and the chromaticity coordinates a^* (red-green axis) and b^* (blue-yellow axis) were obtained. These data were used to calculate the hue angle (h^*), saturation (C^*), color difference (ΔE^*) and change in saturation (ΔC^*), which were determined according Equations 2, 3, 4 and 5. Changes in lightness (ΔL^*) and chromaticity coordinates (Δa^*, Δb^*) were calculated according to Charrier et al. (2002).

$$h^* = \arctan \left(\frac{b^*}{a^*} \right) \qquad \text{Eq. (2)}$$

$$C^* = \sqrt{a^{*2} + b^{*2}} \qquad \text{Eq. (3)}$$

$$\Delta E^* = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}} \qquad \text{Eq. (4)}$$

$$\Delta C^* = \sqrt{\Delta a^{*2} + \Delta b^{*2}} \qquad \text{Eq. (5)}$$

Modelling the Improvement

Simple linear regression analysis was run. All colorimetric variables were employed as predictor of the following dimensional stability properties: EMC, PTS, WA24H and ASE. Coefficient of determination (R^2), standard error of the estimate (SEE) and significance of the coefficients were observed for choosing the best model. The statistical analysis was run using the software package SPSS 13.0 for Windows.

Results and Discussion

Thermal Treatment

Figure 1 shows the change in color of the boards treated at 190ºC and 220ºC. The darkening of the board is clear, and was more pronounced in boards treated at 220ºC. This way, the change in lightness (ΔL^*) was greater for boards treated at this temperature in comparison with those treated at 190ºC: 12.7 x 3.9. The treated board also lost in yellowness, in other words, the reduction in b^* (Δb^*) was about 0.68 at 190ºC and 5.6 at 220ºC. The board redness (a*) was also modified and a slight improvement was observed: 1.3 at 190ºC and 1.4 at 220ºC.

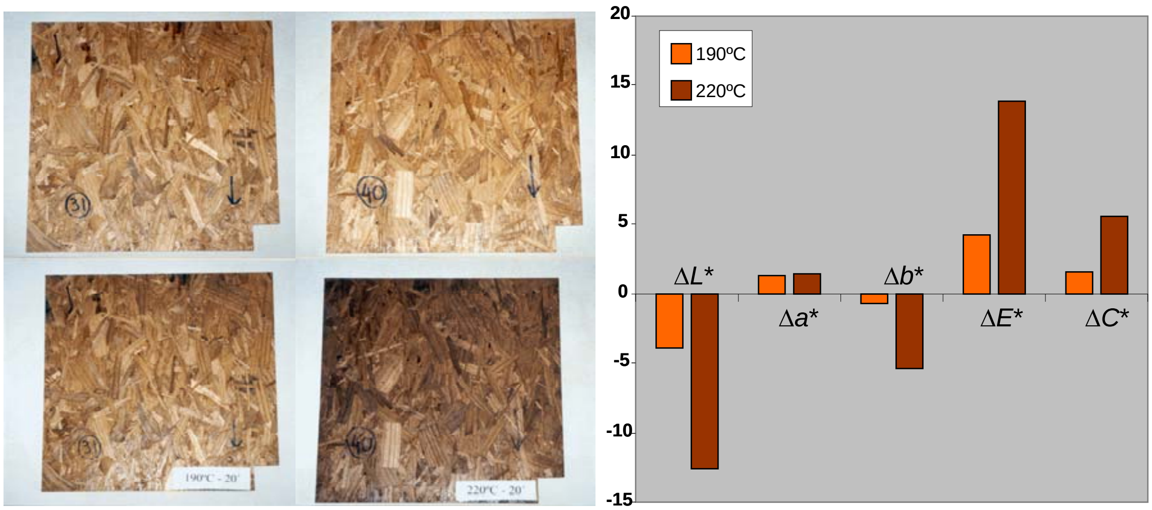

Figure 1. Surface color appearance of the board before (above) and after (below) the thermal treatment and changes in colorimetric variables at 190ºC and 220ºC.

The TS24H of untreated boards was about 19.2%, which means it did not meet the maximum value allowed by the Canadian Standard Association (15%) for 12.5 mm thickness boards. On the other hand, the value for treated board ranged from 14.2% (T1) to 9.4% (T6). In this way, all treated board met the CSA requirement.

During the thermal treatment the boards were heated above the glass transition temperature of the wood matrix. At this condition those stresses imposed by the hot-pressing were released, and the treated boards shrank at a lower intensity than the untreated boards. This way, the thermal treatment reduced the part of the thickness swelling due to these stresses, which are the unrecoverable part of the thickness dimensional movement. In this context, the PTS values were pronouncedly reduced and the thickness swelling of the treated boards happened mainly due to the hygroscopic behavior of the wood material.

However, the thermal treatment also reduced the water adsorption: the EMC values ranged from 7.7% (T1) to 5.1% (T6). EMC could be reduced because the thermal treatment imparted chemical degradation, despite the mild conditions employed. It is well-known that at these temperatures (190ºC/220ºC) degradation of the hemicelluloses already happens, reducing the sites for adsorption of water molecules. Beyond the hemicelluloses degradation, the thermal treatment also leads to the formation of cross-linked net (Kosikova et al. 1999) and modifies the degree of celluloses cristallinity (Petrissáns et al. 2003), both playing important roles on the reduction of EMC of heat-treated material.

Figure 2 presents the value of ASE and AME for every studied treatment. It can be observed that the higher the temperature, the higher the ASE and AME. The effect of the duration was not evident for boards treated at 190 ºC. However, at 220 ºC the longer treatment improved these values.

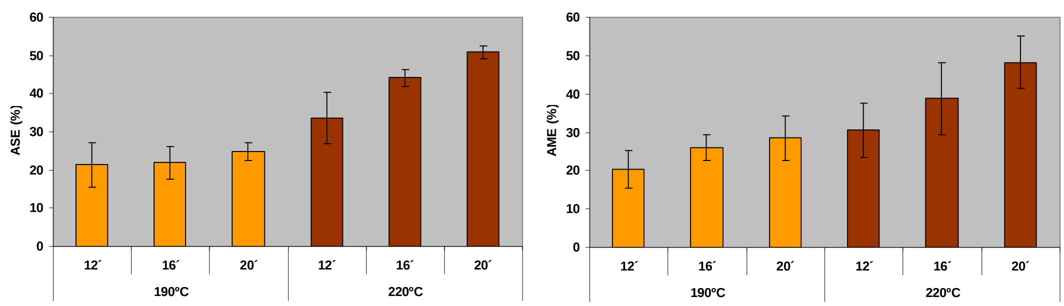

Figure 2. Anti-shrink efficiency and anti-moisture efficiency according to the temperature and time of the thermal treatment.

The models for predicting the improvement of the dimensional stability are presented in Figure 3. The generated models explained 37.1 to 64.4% of the variation of the dimensional stability properties. The main colorimetric variables which entered the models were *L**, *b** and Δ*E**. It is clear that the ASE and PTS models had better coefficient of determination (R^2) in comparison with the EMC and WA24H models: R^2 about 37.1%. The colorimetric variables might be more effective as predictors.

According to these models, the ASE is improved as the surface of the board becomes darker, in other words, the board loses in lightness (L^*). This means that the thickness swelling of the treated boards is reduced comparatively to untreated ones the more intensive the darkening process of the board is. The same trend is observed for coordinate b^*: the board loses yellowness and the thickness swelling is reduced (i.e. ASE is improved).

The loss in lightness and yellowness was more intensive for longer treatments, which presented the higher ASE values as well. This way, as the treatment was prolonged the release of those compression stresses was more effective (lower PTS values) and the boards shrank at lower intensity than the shorter treatments. In this context, it is clear that the improvement of the dimensional stability (high ASE values) can be achieved by intensive changing in color (high ΔE^* values); there is a direct relationship between these parameters.

However, the accuracy of the models for predicting EMC and WA24H can be improved, probably by entering other variables. Del Menezzi and Tomaselli (2006) found that loss of weight imparted by the thermal treatment had a strong correlation with EMC (r = -0.713) and TS24H (r = -0.621).

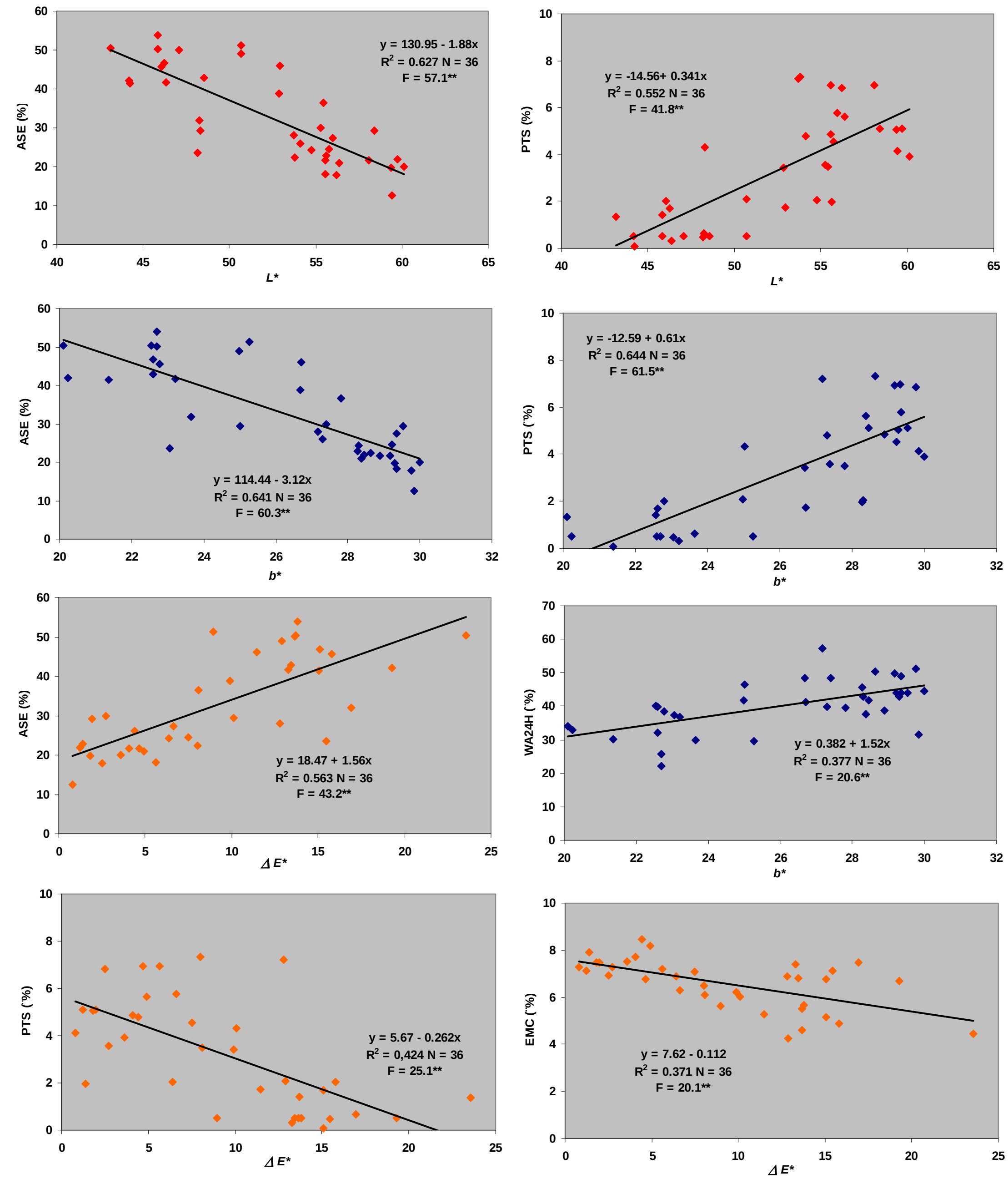

Figure 3. Models for predicting dimensional stability properties using colorimetric variables.

Conclusions

Commercial oriented strandboards were thermally treated at mild conditions. All properties regarding dimensional stability were improved. This improvement could be modeled by using the colorimetric variables of the treated boards. In general, the treated boards lost lightness and yellowness, but gained in redness, which imparts a high degree of change in color of the boards. This effect is more pronounced if a more severe treatment is applied. Finally, it can be concluded that color variation is a suitable method to estimate the dimensional stability improvement observed in post-treated OSB.

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