DIMENSIONAL STABILITY OF PLYWOOD PANEL PRODUCED FROM AN ADHESIVE FORMULATION LOADED WITH A PERCENTAGE OF MINT WASTE

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ABSTRACT

To investigate the influence of changes in relative humidity on panel moisture and resulting dimensional changes for the panel, experiments were conducted on two samples of plywood manufactured with two adhesive formulations loaded by two types of fillers, as a adhesive formulation is characterized in that it consists of a powder based on starch (AF-REF) and other consists of a mixture between the starch-based powder and the mint waste (AF-WM).

By comparing the two samples tested, the plywood manufactured using adhesive formulation (AF-WM) has a low dimensional variation and a low dispersion of moisture relative to the plywood manufactured using adhesive formulation (AF-REF), however, the plywood panel manufactured from (AF-WM) showed better resistance to variation in relative humidity.

On the other hand, the optical microscope was allowed to observe the vessels, woody rays, fibers and the glue line in plywood tested, the specimen taken in the transverse direction of the plywood shows that the vessels are clear on the exposed face, therefore the vessels are responsible for adsorption and desorption the moisture from different climatic environment which allows concluding that the dimensional
variation and moisture dispersion in the transverse direction are higher relative to the longitudinal direction.

**Keywords:** Adhesive Formulation, Waste Mint, Plywood, Dimensional Variation, Moisture, Optical Microscope.

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1. INTRODUCTION

Wood based products such as plywood are increasingly used in building construction due to their advantage of low energy consumption and CO$_2$-emission [1, 2, 3].

Plywood panels are created by gluing veneers together, layer by layer, using glue and the natural strength of the wood’s grain helps to create rigid, strong wooden panels. The grains of alternate layers are arranged at right angles. Expansion or contraction within the plane of the board of one veneer is restricted by the wood fibres in the adjacent veneer. The resulting panel has similar strength and shrinkage properties in the directions parallel to the plane of the board and the large dimensional and strength variations that occur across the grain in solid wood are eliminated.

All wood products contain moisture, from saturated fresh cut logs to the fairly dry wooden indoor structures and furniture. Moisture in wood is stored as either bound water or free water. Bound water is held within cell walls by bonding forces between hydrogen molecules of water and hydroxyl molecules of the wood cellulose. Free water is contained in the cell lumens/cavities and is held by surface tension. A microscopic view of wood is shown in Figure 1.

Plywood veneers are made by rotating the log and peeling a thin veneer from the log, moisture transfer in the veneer in the direction of the thin dimensions is equivalent to moisture transfer in the radial direction of the log. When these veneers are assembled and used in buildings and furniture, the moisture transfer through the exposed surface and into the plywood is equivalent to moisture transfer in the radial direction of the original log. Because of the rotary peeled veneers, plywood will have more uniform moisture transfer characteristics than raw timber for example, which will have moisture transfer in directions that are both radial and tangential to the wood grains [4].

![Figure 1](http://www.iaeme.com/ijmet/issues.asp?JType=IJMET&VType=9&IType=13)

**Figure 1.** Picture of spruce plywood showing the cross-banded construction and the moisture transfer direction. Scanning electron microscope picture of spruce heartwood showing the cell walls and the cell lumens as well as the main direction of moisture transfer for plywood [5].
Wood-based panels are hygroscopic and since their surface to volume ratio is very high, physical deformations and cracks are possible. In the case of plywood the strength properties of the glue lines are affected by changing moisture, resulting in a risk of delamination and panel failure [6].

The impact of hygroscopic materials depends on many factors: the amount and type of materials in a given room, the outdoor climate, the outdoor ventilation rate and the moisture production rate, which also depends on the indoor temperature and RH [7]. During warm and humid outdoor conditions, hygroscopic materials (wooden paneling, porous wood fiber board and cellulose insulation) may reduce the peak humidity in a bedroom by up to 35%, 30% and 20% RH when the ventilation rate is 0.1, 0.5 and 1 ach, respectively [8,9].

At a ventilation rate of 0.5 ach, these reductions in peak indoor relative humidity result in a 10–20% reduction in the percent dissatisfied with warm respiratory comfort and a 20–30% reduction in the percent dissatisfied with perceived air quality.

Dimensional stability has been one of the most investigated characteristics of wood and wood-based panels. The hygroscopic nature of the wood material comes from the hydroxyl groups of the cell wall polymers.

The dimensional stability of wood-based panels is affected by several variables such as wood species, panel density, type and concentration of adhesive, sizing efficiency and pressing conditions [10, 11].

The wood species has an influence on the swelling in thickness of the wood-based panels when considering the density and the chemical properties affecting the polymerization of the adhesive, some studies claim that the hygroscopic expansion of wood is dependent on the density of the cell walls. These studies have shown that the swelling is proportional to the density of the wood [12].

The presence of mature wood and juvenile wood also has an impact on the hygroscopic characteristics of wood, such as embossed panels produced with juvenile Pinus taeda wood has reduced swelling and water absorption and higher linear expansion [13].

The acidity of wood and its chemical characteristics such as pH and buffer capacity will also play an important role in dimensional stability as these properties affect the polymerization of certain adhesives [14]. For example, the urea-formaldehyde adhesive requires acidic conditions to polymerize and incomplete polymerization will induce a greater swelling. Buffer capacity is the ability to be in contact with a more acidic or basic substance without changing the pH. This will affect the polymerization of the adhesive.

The type, distribution and concentration of adhesive have a significant impact on the dimensional stability and mechanical properties of wood-based panels.

The adhesive itself might act as a toxicant to invading fungi [15, 16, 17, 18], and it can function as a physical barrier and thus, effectively prevents water uptake [19]. However, the glue line can also cause water entrapment resulting a decrease in mechanical properties, initiating fungal growth and physical deformation of plywood [20, 21].

On the other hand, most plywood factories use a urea-formaldehyde (UF) adhesive for indoor application and melamine urea formaldehyde (MUF) or phenol formaldehyde (PF) resins for outdoor or semi-outdoor application.

The use of different types of fillers, such as walnut flour, Douglas fir powder, alder bark powder and wood powder, is used to reduce the cost of UF adhesives. It is also used to control penetration into the wood fiber and to moderate the strength properties to suit the materials to be bonded.
For this reason it is very interesting to develop new adhesive formulations by adding fillers that can improve the weather resistance.

The objectives of this work is to valorize the mint waste in the wood-based panel industry and to use mint waste as filler for the manufacture plywood panel to show the effect mint waste on the dimensional variation and the moisture dispersion of the plywood panel.

2. MATERIALS AND METHODS

2.1. Preparation of adhesive formulation

The adhesive formulation is characterized in that it consists of an aqueous resin (urea-formaldehyde) having the following characteristics: Dry extract (105 ° C. for 3 h) ≈ 65% and initial viscosity at 20 ° C ≈ 500 cp. It contains ammonium sulphate which acts as the main hardener, and urea as a retarder. Also, significant percentages of waste mint dried and crushed and another starch-based powdered filler used in the formulation as thickeners. Finally, a 100% water supplement to dissolve the constituents of the mixture (AF-WM). On the other hand, an adhesive formulation marketed on the local wood market is used as a reference (AF-REF). (Table 1)

<table>
<thead>
<tr>
<th>Constituents</th>
<th>(AF-WM) Percentage (%)</th>
<th>(AF-REF) Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urea-formaldehyde resin</td>
<td>51.02</td>
<td>51.02</td>
</tr>
<tr>
<td>Water</td>
<td>16.33</td>
<td>16.33</td>
</tr>
<tr>
<td>Load 1 : Starch-based powder</td>
<td>22.45</td>
<td>27.04</td>
</tr>
<tr>
<td>Load 2 : Mint waste</td>
<td>4.59</td>
<td>0.00</td>
</tr>
<tr>
<td>Urea</td>
<td>2.55</td>
<td>2.55</td>
</tr>
<tr>
<td>Ammonium sulphate</td>
<td>3.06</td>
<td>3.06</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

2.2. Preparation of plywood samples

The plywood was composed of veneer sheets from different species, of the following dimensions: 2100 × 1000 × 4 mm³. The face and back of plywood were made with a wood species of kapok tree, while the core was made with a wood species of okoumé. The folds are placed symmetrically on either side of a central ply (core), which gives an odd number of folds (3 plies) and a balanced structure.

The veneer sheets have been dried in order to keep the standard moisture content for each type of veneer (Soul: 5% to 8% moisture content / Face: Moisture content of 8 % To 14%).

The various components of the panel were assembled using a tacky mixture. By using a roller sizing machine, with a basis weight of 373 g / m² of the mint waste sticky formulation and distributed on both sides.

After the bonding step, the pressing operations were carried out, these operations consisting in:

- Pre-press the panel in cold form at a pressure of 15 bar and at ambient temperature, in order to avoid clogging of the adhesive when waiting for introduction to the press.
- Hot press the panel under a pressure of 50 bar and at a temperature of 98 ° C for 4 min, this step is an indicator of the total productivity of the production.
2.3. Determination of the dimensional variations under the influence of variation of the relative humidity:
The determination of the dimensional variations under the influence of variation of the relative humidity of two plywood panels for interior applications made with two different adhesive formulations (AF-REF) and (AF-WM) was carried out according to the EN 318 standard [22], using test pieces measure (300 ± 2) mm × (50 ± 2) mm × (panel thickness).

Two sets of four specimens were taken from each panel in both directions of the panel to obtain a total of 16 specimens per panel.

The specimens were prepared with the appropriate markings. The ink marking marks were placed on the center line of the test piece at 50 mm from the ends and at the midpoint, glass plates at least 1 mm thick were glued to the ends of the test piece, then metal studs were separated from each other by 250 mm and about 25 mm from each end (Figure 2).

![Figure 2. Specimen of 300 mm in length with glass plates and metal studs](image)

The two sets of specimens were conditioned to a constant mass for each of the steps (figure 3) shown in the table:

<table>
<thead>
<tr>
<th>Step n°</th>
<th>Set n°1</th>
<th>Set n°2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20 °C, 30% relative humidity</td>
<td>20°C, 85% relative humidity</td>
</tr>
<tr>
<td>2</td>
<td>20°C, 65% relative humidity</td>
<td>20°C, 65% relative humidity</td>
</tr>
<tr>
<td>3</td>
<td>20°C, 85% relative humidity</td>
<td>20°C, 30% relative humidity</td>
</tr>
</tbody>
</table>
The relative variation in length and thickness for a change in relative humidity were measured following three cycles of adsorption/desorption between 30 and 80 % RH. The relative humidity conditions were obtained using a climate chamber, model CHALLENGE 340.

For each specimen, the relative variation in length and thickness for a change in relative humidity from 30% to 85%, were calculated as follows:

\[
\begin{align*}
\delta l_{65,85} &= \frac{l_{85} - l_{65}}{l_{65}} \times 100 \\
\delta l_{65,30} &= \frac{l_{30} - l_{65}}{l_{65}} \times 100 \\
\delta t_{65,85} &= \frac{t_{85} - t_{65}}{t_{65}} \times 100 \\
\delta t_{65,30} &= \frac{t_{30} - t_{65}}{t_{65}} \times 100
\end{align*}
\]

Where:

- \(l_{85}\) is the length between the measuring points at 20 °C and 85% relative humidity, in millimeters;
- \(l_{65}\) is the length between the measuring points at 20 °C and 65% relative humidity, in millimeters;
- \(l_{30}\) is the length between the measuring points at 20 °C and 30% relative humidity, in millimeters;
- \(\delta l_{65,85}\) is the relative change in length for a change in relative humidity from 65% to 85%, in millimeters per meter;
- \(\delta l_{65,30}\) is the relative change in length for a change in relative humidity from 65% to 30%, in millimeters per meter.
- \(t_{85}\) is the average thickness of three measurement points at 20 °C and 85% relative humidity, in millimeters;
- \(t_{65}\) is the average thickness of three measurement points at 20 °C and 65% relative humidity, in millimeters;
- \(t_{30}\) is the average thickness of three measurement points at 20 °C and 30% relative humidity, in millimeters;
- \(\delta t_{65,85}\) is the relative change in thickness for a change in relative humidity from 65% to 85%, in percentage;
- \(\delta t_{65,30}\) is the relative change in thickness for a change in relative humidity from 65% to 30%, in percentage.

2.4. Determination of humidity

The humidity of each specimen for the three ambiances of steps 2 and 3 was calculated in accordance with EN 322 [23] by means of the dimensional change determination results.

\[
H(\%) = \frac{M_h - M_0}{M_0} \times 100
\]

Where:

- \(M_h\) is the initial mass at 20 °C and 65% relative humidity, 20 °C and 85% relative humidity or 20 °C and 30% relative humidity, in grams.
- \(M_0\) is the mass after drying, in grams.
2.5. Statistical analysis
The obtained data were analyzed using one-way ANOVA for humidity dispersion and variations in length and thickness properties (p = 0.05) from the SPSS statistical software program.

2.6. Optical microscopy analysis
Observations were made on the sample of the adhesive formulation (AF-WM) and the sample of plywood manufactured with (AF-WM) taken in the transverse direction after the three conditioning cycles. The light passes through the sample and arrives in the lens that gives the object an enlarged image.

3. RESULTS AND DISCUSSION

3.1. Adhesive formulation effect on the dimensional variation of plywood panels

Tables 3 and 4 present the results after the conditioning steps of two plywood samples manufactured using two adhesive formulations (AF-REF) and (AF-WM).

The plywood panel produced from (AF-WM) showed a small variation in moisture, length and thickness after steps 2 and 3 of the conditioning cycles. The adhesive formulation (AF-WM) promoted a small increase of humidity the panel for the environment 20°C, 85% relative humidity after conditioning cycles of 13.7 to 13.0 % (longitudinal direction) and 13.6 to 12.6 % (transverse direction).

In the environment 20°C, 30% relative humidity, the plywood manufactured from (AF-WM) has a small decrease of the humidity the panel of 2.9 to 3.2 % (longitudinal direction) and of 2.8 to 3.1 % (transverse direction).

After the conditioning cycles, the variation in the length showed a difference between the two samples of plywood.

For a relative humidity change of 65% to 85%, the panel manufactured from (AF-WM) showed a small variation in length of 0.1 mm / m in the transverse direction, and 0.1 mm / m in the longitudinal direction, compared to the panel manufactured from (AF-REF) which has a relative length variation of 0.3 mm / m in the transverse direction and 0.3 mm / m in the longitudinal direction. In the other hand, the change in relative humidity from 65% to 30% has approximately similar results in absolute value of the relative change in length for a change in relative humidity from 65% to 85%, positive and negative values for length variation for relative humidity changes of 65% to 85% and 65% to 30% are due to expansion and contraction of test specimens tested during cycles conditioning. Tables 3 and 4 also show the relative change in thickness for a relative humidity change of 65% to 85% and 65% to 30%, the plywood panel manufactured from (AF-WM) presents a small variation in the thickness with regard to panel manufactured from (AF-REF). The change in relative humidity from 65% to 85% resulted in a swelling in thickness for both plywood panels. Compared with the results found for the two panels manufactured with the adhesive formulations (AF-WM) and (AF-REF), we notice that the variation of the relative humidity from 65% to 30% shrunk the specimens of 2.6% in the transverse direction and 2.2% in the longitudinal direction for the panel manufactured from (AF-REF), and 1.6% in the transverse direction and 1.1% in the longitudinal direction for the panel manufactured from (AF-WM). Moreover, the results found for the variations of the humidity and the dimensional variation on the two sets tested for the two panels showed that there is a difference between the results found in the transverse direction and in the longitudinal direction, such as that the transverse direction showed a great
Dimensional Stability of Plywood Panel Produced From An Adhesive Formulation Loaded with A Percentage of Mint Waste
dispersion of moisture and variations of length and thickness, compared to the longitudinal direction.

Tables 5, 6, 7 show the results of ANOVA for the properties of moisture dispersion and variations in length and thickness.

Statistical analysis by ANOVA showed that the difference between the humidity variations and the dimensional variations for the two panels was statistically significant (F<\text{F}_{\text{obs}}) and (\text{Sig}<0.05).

In addition, the type of adhesive formulation used in the manufacture of plywood panel has shown a significant impact on moisture variability and dimensional variation. In general, the adhesive formulation (AF-WM) panel exhibited lower moisture dispersion and length and thickness variations than the adhesive formulation (AF-REF).

**Table 3.** Results obtained for humidity variations and dimensional variations for Set N°1

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>FC-REF</th>
<th>FC-MT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average humidity for the environment 20°C, 65% relative humidity in the transverse direction</td>
<td>%</td>
<td>11.4</td>
<td>11.1</td>
</tr>
<tr>
<td>Average humidity for the environment 20°C, 65% relative humidity in the longitudinal direction</td>
<td>%</td>
<td>11.6</td>
<td>10.9</td>
</tr>
<tr>
<td>Average humidity for the environment 20°C, 85% relative humidity in the transverse direction</td>
<td>%</td>
<td>13.7</td>
<td>13.0</td>
</tr>
<tr>
<td>Average humidity for the environment 20°C, 85% relative humidity in the longitudinal direction</td>
<td>%</td>
<td>13.6</td>
<td>12.6</td>
</tr>
<tr>
<td>Average relative length variation for a relative humidity change of 65% to 85% in the transverse direction</td>
<td>mm/mm</td>
<td>0.3</td>
<td>0.1</td>
</tr>
<tr>
<td>Average relative length variation for a relative humidity variation from 65% to 85% in the longitudinal direction</td>
<td>mm/mm</td>
<td>0.3</td>
<td>0.1</td>
</tr>
<tr>
<td>Average relative variation thickness relative to variation of humidity from 65% to 85% in the transverse direction</td>
<td>%</td>
<td>2.9</td>
<td>1.7</td>
</tr>
<tr>
<td>Average relative thickness variation for a relative humidity change of 65% to 85% in the longitudinal direction</td>
<td>%</td>
<td>2.7</td>
<td>1.6</td>
</tr>
</tbody>
</table>

**Table 4.** Results obtained for humidity variations and dimensional variations for Set N°2

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>FC-REF</th>
<th>FC-MT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average humidity for the environment 20°C, 65% relative humidity in the longitudinal direction</td>
<td>%</td>
<td>11.1</td>
<td>11.0</td>
</tr>
<tr>
<td>Average humidity for the environment 20°C, 65% relative humidity in the transversal direction</td>
<td>%</td>
<td>11.0</td>
<td>11.1</td>
</tr>
<tr>
<td>Average humidity for the environment 20°C, 30% relative humidity in the longitudinal direction</td>
<td>%</td>
<td>2.9</td>
<td>3.2</td>
</tr>
<tr>
<td>Average humidity for the environment 20°C, 30% relative humidity in the transversal direction</td>
<td>%</td>
<td>2.8</td>
<td>3.1</td>
</tr>
<tr>
<td>Average relative length change for a relative humidity change of 65% to 30% in the longitudinal direction</td>
<td>mm/mm</td>
<td>-0.3</td>
<td>-0.1</td>
</tr>
<tr>
<td>Average relative length variation for relative humidity variation from 65% to 30% in cross-sectional direction</td>
<td>mm/mm</td>
<td>-0.2</td>
<td>-0.1</td>
</tr>
<tr>
<td>Average relative variation thickness relative to variation of humidity from 65% to 30% in the longitudinal direction</td>
<td>%</td>
<td>-2.6</td>
<td>-1.6</td>
</tr>
<tr>
<td>Average relative thickness variation for a relative humidity change of 65% to 30% in the transverse direction</td>
<td>%</td>
<td>-2.2</td>
<td>-1.1</td>
</tr>
</tbody>
</table>
Table 5. Results of Analysis of Variance - ANOVA for Changes in Moisture

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Analysis of variance (ANOVA) of the humidity for the environment 20 °C, 85% relative humidity in the transverse direction</th>
<th>Analysis of variance (ANOVA) of the humidity for the environment 20 °C, 85% relative humidity in the longitudinal direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sum of squares</td>
<td>Degrees of freedom</td>
<td>Variance</td>
</tr>
<tr>
<td>Between Groups</td>
<td>1.280</td>
<td>1</td>
</tr>
<tr>
<td>Within Groups</td>
<td>0.175</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>1.455</td>
<td>7</td>
</tr>
</tbody>
</table>

Table 6. Results of ANOVA analysis for variance in length

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Analysis of variance (ANOVA) of length for a relative humidity variation of 65% to 85% in the transverse direction</th>
<th>Analysis of variance (ANOVA) of length for a relative humidity variation of 65% to 85% in the longitudinal direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sum of squares</td>
<td>Degrees of freedom</td>
<td>Variance</td>
</tr>
<tr>
<td>Between Groups</td>
<td>0.080</td>
<td>1</td>
</tr>
<tr>
<td>Within Groups</td>
<td>0.072</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>0.152</td>
<td>7</td>
</tr>
</tbody>
</table>

Table 7 Results of ANOVA analysis for variance in thickness

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Analysis of variance (ANOVA) of the thickness for a relative humidity variation of 65% to 85% in the transverse direction</th>
<th>Analysis of variance (ANOVA) of the thickness for a relative humidity variation of 65% to 85% in the longitudinal direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sum of squares</td>
<td>Degrees of freedom</td>
<td>Variance</td>
</tr>
<tr>
<td>Between Groups</td>
<td>2.761</td>
<td>1</td>
</tr>
<tr>
<td>Within Groups</td>
<td>0.578</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>3.339</td>
<td>7</td>
</tr>
</tbody>
</table>

http://www.iueme.com/ IJMET/index.asp 885 editor@iaeme.com
3.2. Imaging of resin impregnation in wood

Optical spectroscopy analysis was used to understand the impact of the adhesive formulation as well as the direction of panel (longitudinal and transverse direction) on the dimensional variation of the plywood.

Optical microscopic results of a sample of UF resin loaded with a mixture of starch-based powder and waste mint (AF-MT) indicate the presence of particles of the waste mint in the adhesive formulation, the figure also shows that the mint waste particles are well dispersed in the adhesive formulation (AF-WM),

![Particle of waste mint](image.png)

**Figure 4.** Optical microscopy of samples of adhesive formulation (AF-WM)

Figures 5 and 6 show the optical microscopy photograph of interface between two layers of plywood panel bonded by adhesive formulation (AF-WM) taken in the longitudinal and the transverse direction of the panel after the three conditioning cycles.

The three veneers constituting the tested plywood have a hardwood structure (presence of vessels, woody rays, parenchyma and fibers), each layer has a different plane (transverse plane and longitudinal plane).

In the black area, we can see the line of glue and adhesive that has penetrated into vessels.

The glue distribution was much more uniform; water uptake can then be hindered more efficiently at the first glue line, which would keep inner layers at a low moisture level. Water desorption in the second and third layer is much slower than the top layer because of the presence of the glue line, acting as a barrier [19].

Depending on the orientation of the bonding planes (longitudinal plane, and transverse plane), the adhesive penetrates more or less into the vessels.

The specimen taken in the transverse direction of the plywood panel (Figure 6), shows that the vessels are clear on the exposed face, which explains that the cutting of the specimen in the transversal facilitates the transfer of humidity in the vessels, consequently the dimensional variation in the transverse direction is higher relative to the longitudinal direction.
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Figure 5. Interface between two layers of plywood glued together by adhesive formulation (AF-WM) taken in the longitudinal direction of the panel

Figure 6. Interface between two layers of plywood glued together by adhesive formulation (AF-WM) taken in the transverse direction of the panel

4. CONCLUSION
Mint waste used as a load in an adhesive formulation based on urea formaldehyde resin can improve the dimensional stability of plywood panels.

In this study, the physical property of dimensional variation on two plywood samples made with two adhesive formulations was investigated.

On the basis of the results data, the following conclusions were drawn:

• Relative changes in the length after the conditioning steps of 20 °C, 85% relative humidity and 20 °C, 30% relative humidity for the plywood sample decreased after the change in adhesive formulation using a percentage of mint waste in the loads.

• The relative variations in the thickness after the conditioning steps of 20 °C, 85% relative humidity and 20 °C, 30% relative humidity for the plywood sample decreased after the change in adhesive formulation using a percentage of mint waste in the loads.
Decreased moisture dispersion for plywood manufactured with the adhesive formulation using a percentage of mint waste in the loads.

A significant difference was found between the two plywood panels for moisture dispersion and variations in length and thickness.

The optical microscope showed that the adhesive formulation made using a percentage of mint waste in the loads has improved the adhesive formulation, making a screen at the adsorption and desorption of humidity in veneer vessels; in addition the transversal direction of the plywood facilitates the transfer of humidity in the vessels.

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