INFLUENCE OF THE MULTIDAY AND CONTINUOUS HOT PRESS ON THE PHYSICAL, MECHANICAL AND FORMALDEHYDE EMISSION PROPERTIES OF THE PARTICLEBOARD

Osman Camlibel¹

¹Kırıkkale University, Kırıkkale Vocational School, Interior Design, Kırıkkale, Turkey.

*Corresponding author: osmancamlibel@kku.edu.tr

Received: February 07, 2021
Accepted: November 10, 2022
Posted online: November 11, 2022

ABSTRACT

In this study, its the influence of according to press, particleboards produced in two different press types which were multiday and continuous hot press, the thickness, density, bending strength, modulus of elasticity, internal bond, surface soundness, withdrawal of screw resistance, moisture, thickness swelling, water absorption, formaldehyde emission content were researched. 18 mm x 2100 mm x 2800 mm size particleboards were manufactured on the production line which was using urea-formaldehyde (F:U;1,07 moles), and 30 % pine, 40 % oak, 20 % beech and 10 % poplar waste mixture of the wood materials. According to results of the tests performed after the multiday and continuous hot press production of the boards; thickness (0,63 %), bending strength (1,27 %), moisture content (0,47 %), thickness swelling (37 %), and water absorption (39,9 %), modulus of elasticity (11,35 %), internal bond (7,22 %) were increased according to multiday hot press while density (2,7 %), surface soundness (18,81 %), withdrawal of screw resistance (14 %) and formaldehyde (57,12 %) decreased. Formaldehyde content, surface soundness, withdrawal of screw resistance are the most prominent properties influenced by continuous hot press.

Keywords: Continuous hot press, formaldehyde content, multiday hot press, particleboard, physical-mechanical properties.
INTRODUCTION

Wood-based particleboard materials are engineered wood-based particleboard materials that are widely used in construction, furniture, interior design by surface decor paper coating, acrylic covering, veneering and painting or other kinds of surface coating. Owing to it cheaper and competitive remarkable is a qualifier product than other expensive wood-based boards. Due to features physical, mechanical strength properties and formaldehyde contents of particleboard is one of the most used panel materials in the furniture or construction industry. The produced particleboard is requested the lowest formaldehyde release according to related standard. According to Ayla (1999) assessed the continuous press systems are replaced the classical production over time. Continuous press systems are used more prominent wood-based panel industrials such as particleboard, medium-density fiberboards, laminate. The production system of continuous presses can be heated and, in some systems, cooled. All this system is made between double continuously rotating steel bent.

Evessen (1984) presented the describes about modern continuous pressing methods and starting with the küsters press process. He was compared to a cost the single-daylight step-pressing process and küster continuous press. Resin type and ratio in the core and surface layers, press time and temperature, wood types and mixtures are some of the essential factors that have influenced the physical and mechanical properties of particleboards.

The effects of these factors are researched by the investigator in an extensive study as followings; according to Nemli (2002) work evaluated the production parameters to obtain higher physical and mechanical properties, and formaldehyde emission of particleboards produces using E1 type resin. He explained that an increase in the
temperature, time and pressure in the pressing process develop the technological properties of particleboards.

According to the investigate of Godbille (2002) determined a two-dimensional numeric model for continuous hot press (CHP) of particle board (PB) and the effects of parameters on the process. Thoemen and Humphrey (2003) provided a numerical model that is directly applicable to modelling the continuous pressing process. The researchers used variable parameters in this continuous press modeling, such as “changing mat thickness and steel belt temperatures in the feed direction, and the escape of vapor and air through the horizontal surfaces immediately in front of and behind the press, and the possibility to vary the mat thickness across the width of the press”. According to Nemli et al. (2004) the effects of the continuous press system applied in particle board production as a result of developing technology on the physical and mechanical properties of the particle board have investigated. They have investigated that the particleboards were produced in 2800 mm x 2100 mm x 18 mm dimensions, 0,68 g/cm³ density with urea formaldehyde resin by the classic (single layer press), and continuous press. In their studies, thickness, thickness swelling, water absorption, bending strength, modulus of elasticity, internal bond, screw holding performance of particleboard were determined.

The properties of particleboard are affected by press types. Arruda et al. (2011) using a mixture of bamboo with Pinus taeda wood particles was manufactured particleboard (650 kg/m³). In their studies, particleboards were bonded using 8 % content of urea-formaldehyde and phenol-formaldehyde resins, based on a dry weight mat. It has been better dimensional stability made of phenol-formaldehyde, than urea formaldehyde resins. Candan et al. (2012) 18 mm thick medium density fiberboards (MDF) were produced by using 70 % beech and 30 % birch wood chips. Physical properties were investigated under the effect of continuous press speed (6,9 m/min and
7.4 m/min) and 220 °C temperature. They explained that as the continuous press speed increases, the thickness swelling (2 h and 24 h) values of the board decrease. They explained that effective press performance can be used in production with the amount of resin and the humidity of the board.

Iswanto et al. (2013) evaluated the effects of pressing temperature and pressing time on the quality of the particleboard treated by dipping in 1 % acetic acid solution. Ciobanu et al. (2014) have investigated the effects of some production parameters of the continuous press using melamine-urea-formaldehyde and polymeric diphenylmethane diisocyanate resins additive oriented strand boards. Ciobanu et al. (2014) have produced oriented strand boards (OSB). They were used continuous press speed (500 mm/s to 1190 mm/s), temperature (190 °C to 250 °C) pressure (1.5 MPa to 5 MPa), melamine-urea-formaldehyde and polymeric diphenylmethane diisocyanate resins, mixes of softwood and hardwood species. Researchers explained that physical and mechanical properties of oriented strand board (OSB) are related to press speed and press factor, and low speed increases all mechanical properties.

Kord et al. (2015) have investigated that using reed stems are produced by three-layer particleboard. They have made variable parameters mixed ratio of reed and wood particles (0:100, 25:75, 50:50, 75:25 and 100:0 in the surface, and core layers), press temperature (170 °C, 180 °C, 190 °C) and pressing time (5 min, 6 min, 7 min). According to the results physical, and mechanical properties of particleboards have increased the increase of reed particles content. The particleboards are manufactured both single storey press and continuous press and the produced particleboards are tested of technological properties. According to test results, the single-storey presses are produced boards of higher quality than continuous press boards. However, a continuous pressing system has many advantages, so it is preferred by the factory (Güler and Sancar 2016).
Funk et al. (2017) have researched the use of a new type of functional inorganic additive to reduce formaldehyde emissions from particleboard. According to the results, diatomaceous earth inorganic additive in particleboard reduced free formaldehyde release. Maraghi et al. (2018) studied the effect of temperature on the physical and mechanical properties of particleboards. Istek et al. (2018) presented that the troubles related to formaldehyde and reduction methods. Zhu et al. (2018) explained that continuous hot presses are one of the main equipment types for medium density fiberboard (MDF) production. In addition to their work, they studied present numerical analyses of continuous hot press for medium density fiberboard (MDF) or particle board production (PB). Barragan-Lucas et al. (2019) have investigated the effects of pressing temperature and using resin on the formaldehyde content, physical, and mechanical properties of the particleboards. The particleboards have produced by banana pseudo-stem.

Saad et al. (2019) have investigated that the production of particleboard by optimizing the composition, press temperature and press time parameters using pine bark and empty fruit bunches. They have determined the density, moisture content, internal bold of particleboards properties. Solt et al. (2019) have investigated that the individual adhesive systems based on preferred product processes, formaldehyde emission parameters, and technological parameters suitable for particleboard production.

According to the studies, they have worked on the evaluation of synthetic and renewable-based adhesives (without formaldehyde) in the production of wood-based products. Nitu et al. (2020) have studied the effects of particle mixing ratios, press temperatures, and pressing time on the mechanical properties and thermal stability of the jute stick binderless particleboards.
Camlibel (2020) evaluated the effects of press time, press pressure, press temperature, press speed on the particleboard’s physical properties and board density. Ferrandez-Villena et al. (2020) have investigated that the effects of particle size, pressing time and pressing cycle on the mechanical, and physical properties of particleboards produced using Arundo donax L. According to the researched that mechanical properties are increased with the increase in pressing time whereas shorter pressing time caused better physical property values. Shupin et al. (2020) have produced three-layer low-density particleboard (400 kg/m³) from using wood particles with expanded polystyrene content ratio (0 %, 2.5 %, 5 %, 7.5 %, 10 %, 12.5 %). According to the results, the bending, and internal bond properties of boards additive expanded polystyrene are remarkably improved, and the thickness swelling is decreased.

Yel et al. (2020) investigated that the influence of press temperature on some properties of three-layer cement bonded particleboard manufactured from the particles of spruce (Picea orientalis) and poplar (Populus tremula). According to the results, press temperature essentially affected the properties of cement-bonded particleboard as dependent on the wood types. Lv et al. (2020) investigated an indefinite unsuccess mode and effects analysis technique integrated with fault and insufficiency analysis technique for the quality control of medium-density fiberboard (MDF) production using continuous hot pressing.

However, the effects of particleboards formaldehyde content, some physical and mechanical properties of particleboards, produced by continuous hot press, and multiday hot press were assessed. According to both particleboards test results, this study has assessed to performance of particleboards of tests results using two multiday and continuous hot press models.
MATERIALS AND METHODS

Materials

Scots pine (Pinus sylvestris), beech (Fagus orientalis), oak (Quercus robur) and poplar tree cover (Populus alba) wood species were used for particle boards production. These wood species were brought from the Western Black Sea, Kastamonu and Bolu stand, respectively.

Resin

Urea Formaldehyde (F:U; 1,07 moles) was produced by the Kastamonu Integrated Glue Plant in Kastamonu Organized Industrial Zone in Turkey. Properties of the produced (F:U; 1,07 moles) resin were showed in Table 1.

Table 1: Properties of used resin.

<table>
<thead>
<tr>
<th>Solid matter (%)</th>
<th>Mole ratio (U/F)</th>
<th>Density (g/cm³)</th>
<th>Viscosity-second (25 °C cps)</th>
<th>Gel time-second (100 °C) (20 % (NH₄)₂SO₄)</th>
<th>pH</th>
<th>Free Formaldehyde (%)</th>
<th>Metilol groups (%)</th>
<th>Shelf time (day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>62 ± 1</td>
<td>1,07</td>
<td>1,228</td>
<td>20 -35</td>
<td>30 - 65</td>
<td>7-8,2</td>
<td>0,2</td>
<td>12 -15</td>
<td>75</td>
</tr>
</tbody>
</table>

cps: centipoise (unit for measuring dynamic viscosity)

Ammonium sulfate (hardener agent)

Ammonium sulfate chemicals were supplied from İzmit city. The hardener was prepared as 20 % solution. Hardener agent was used of UF resin in particle board production. Resin density and pH values were 0,95 g/cm³ and 6,4 g/cm³, respectively. and 6,5 g/cm³, respectively.

Paraffin

Paraffin was white to an off-white liquid solution. Paraffin was supplied by Mercan Chemical Company in Denizli, Turkey. Paraffin had chemical values which were solid content 60 %, pH; 9-11, viscosity; 12-13 second, density; 0,96 g/cm³.
Production Parameters

Hardwood (60 %) and softwood (40 %) were used particleboard production at the kind of materials. Mixture chips of the scotch pine (*Pinus sylvestris*) 30 %, poplar (*Populus alba*) wood waste 10 %, sessile oak (*Quercus robur*) 40 %, beech (*Fagus orientalis*) 20 % were used to manufacture particleboard materials. The consumed wood chips for 1 m³ particleboard materials were presented in Table 2. The resin properties are shown in Table 1. The 1 m³ particleboard includes as following; 1,07 moles urea formaldehyde resin, 20 % ammonium sulfate as solution and 0,95 g/cm³ off-white liquid paraffin. Particleboards were produced both multiday press and continuous press. Multiday press and continuous press were used the same production includes parameters.

<table>
<thead>
<tr>
<th>Table 2: Production parameters of particleboard.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameters</td>
</tr>
<tr>
<td>Softwood (Scotch pine) (%)</td>
</tr>
<tr>
<td>Hardwood (Oak) (%)</td>
</tr>
<tr>
<td>Hardwood (Beech) (%)</td>
</tr>
<tr>
<td>Softwood (Poplar tree cover) (%)</td>
</tr>
<tr>
<td>Resin (F:U) moles ratio</td>
</tr>
<tr>
<td>Resin solid (%)</td>
</tr>
<tr>
<td>Resin solid according to dry chips (%)</td>
</tr>
<tr>
<td>Hardener according to resin solid ratio (%)</td>
</tr>
<tr>
<td>Paraffin according to dry chips (%)</td>
</tr>
<tr>
<td>Chips moisture (%)</td>
</tr>
<tr>
<td>Press temperature (°C)</td>
</tr>
<tr>
<td>Press speed (mm/s)</td>
</tr>
<tr>
<td>Press time (s)</td>
</tr>
</tbody>
</table>

SL: surface-layer, CL: core-layer.

Production of particleboards

In this study, 30 % scotch pine (*Pinus slyvestris*), 40 % sessile oak (*Quercus robur*), beech (*Fagus orientalis*) 20 %, 10 % poplar (*Populus alba*) wood waste were used. Firstly, wood materials were chipped in the chipping machine as rough chips.
According to the wood species, chips were transported to separately chips department in the silos with the belt conveyor system. The mixed chips were adjusted according to the production parameters with the help of the discharge screw under the silos. Then raw chips were transformed separately surface layer chips and core layer chips by an industrial-scale knife ring flaker mill (Pullmann Maschinenfabrik GmbH & Co. KG, Zweibrücken, Germany). According to CL and SL chips were dried separately 2,5 % surface layer and core layer 1,5 % - 1,75 % moisture by horizontal rotary roller dryer. then dried chips were sieved on a shaking sieve. Chips were transported by conveyor bant. According to chips size as CL and SL chips were stored in two different silos. According to dry chip percentage weight, SL and CL chips were added resin, hardener and paraffin according to production parameters values by dosing station. Then, chips were formed before prepress particleboard form (bottom, core, surface layers) by forming station.

The particleboard form was pressed by the pre-press station and then made ready for hot press. According to product parameters values, particleboards were produced by multiday hot press and continuous hot press. The particleboards produced were sized as 18 mm x 2100 mm x 2800 mm dimensions by cut size machine. Then, the particleboards were stored in storage for 5 days. The particleboards were sanded using 40-80 and 100 grit sandpaper by sanding machine.

Particleboards were produced on the production lines of a private company. The flowsheet diagram in Fig. 3 of this study was presented both the multiday hot press and continuous press in Fig. 1 (continuous hot press) and Fig. 2 (multiday hot press).
The tests of particleboards

All tests of the particleboard were made in the test laboratory of the private company. All the particleboards were acclimatized at 20 °C ± 2 °C and 65 % ± 5 % relative humidity according to ISO 554 (1976). Particleboard properties were tested using a laboratory testing machine, IB700 (IMAL SRL, Italy), in compliance with standards.

Physical Tests

The thickness, density, moisture content, thickness swelling, and water absorption of the samples were determined in compliance with the TS EN 324-1 (TSE 1999), TS EN 323 (TSE 1999), TS EN 322 (TSE 1999), TS EN 317 (TSE 1999), and TS EN 317 (TSE 1999) standards, respectively.

Mechanical tests

The bending strength, modulus of elasticity, internal bond, and surface soundness of the particleboard samples were determined in compliance with the TS EN
TS EN 310 (TSE 1999), TS EN 310 (TSE 1999), TS EN 319 (TSE 1999), and TS EN 311 (TSE 2005) standards, respectively.

**Formaldehyde content analysis**

The formaldehyde content of the particleboard was determined in compliance with the TS 4894 EN 120 (TSE 1999) standard.

**Statistical Analysis**

Independent samples T test (Mann-Whitney U) and ANOVA were used to compare means using SPSS software by a computer program. Linear regression analysis (p < 0.05) was performed to identify the relationship between the results of the multiday press and continuous press particleboards.

**RESULTS AND DISCUSSION**

**Physical Tests**

The physical test results as a diagram of particleboard were presented in Fig. 4.
According to statistical analysis (t 0.05:18 =0.000000001), presented in Table 3, no statistically significant differences between the thickness properties of multiday press particleboards and continuous press particleboards were seen. However, the multiday press particleboard was 0.634 % thicker than the continuous press particleboard.

**Table 3:** Statistics for thickness properties of panels.

<table>
<thead>
<tr>
<th>Test of Boards</th>
<th>Groups</th>
<th>N</th>
<th>Average</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>t (95 % CI*)</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness</td>
<td>MHP particleboards</td>
<td>10</td>
<td>17.995</td>
<td>0.018</td>
<td>0.006</td>
<td>11.438</td>
<td>18</td>
<td>0.000000001</td>
</tr>
<tr>
<td></td>
<td>CHP particleboards</td>
<td>10</td>
<td>17.881</td>
<td>0.026</td>
<td>0.008</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Confidence Interval, N: Number of samples, t: the computed test statistic, df: the degrees of freedom, p values: confidence level for a confidence interval, multiday hot press (MHP), continuous hot press (CHP).

According to statistical analysis (t 0.05:18=0.0076), presented in Table 4, no statistically significant differences between the density properties of multiday press particleboards and continuous press particleboards were seen. The densities of both boards were homogeneous. However, continuous press particleboards were 2.70 % more density than the multiday press particleboard. According to Sarı et al. (2012) assessed the density is the essential determinant that influences the board properties.

**Table 4:** Statistics for density properties of boards.

<table>
<thead>
<tr>
<th>Test of Boards</th>
<th>Groups</th>
<th>N</th>
<th>Average</th>
<th>Standard Deviation</th>
<th>Std. Error Mean</th>
<th>t (95 % CI*)</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>MHP particleboards</td>
<td>10</td>
<td>616.29</td>
<td>16.74</td>
<td>5.29</td>
<td>-3.007</td>
<td>18</td>
<td>0.0076</td>
</tr>
<tr>
<td></td>
<td>CHP particleboards</td>
<td>10</td>
<td>633.38</td>
<td>6.53</td>
<td>2.07</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Confidence Interval, N: Number of samples, t: the computed test statistic, df: the degrees of freedom, p values: confidence level for a confidence interval, multiday hot press (MHP), continuous hot press (CHP).
Moisture Content

According to the t-test results ($t_{0.05;18}=0.742$), seen in Table 5, there were statistically significant differences between the moisture content of the multiday press particleboards. The moisture content of the multiday press particleboards was 0.47% higher than the continuous press particleboards. Consequently, it’s seen that multiday press particleboards tend to absorb further moisture.

**Table 5**: Statistics for moisture content properties of boards.

<table>
<thead>
<tr>
<th>Test of Boards</th>
<th>Groups</th>
<th>N</th>
<th>Average</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>$t$ (95% CI*)</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture Content (%)</td>
<td>MHP particleboards</td>
<td>10</td>
<td>6.440</td>
<td>0.207</td>
<td>0.065</td>
<td>0.335</td>
<td>18</td>
<td>0.742</td>
</tr>
<tr>
<td></td>
<td>CHP particleboards</td>
<td>10</td>
<td>6.410</td>
<td>0.194</td>
<td>0.061</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Confidence Interval, N: Number of samples, $t$: the computed test statistic, df: the degrees of freedom, p values: confidence level for a confidence interval, multiday hot press (MHP), continuous hot press (CHP).

Thickness swelling

According to t-test result ($t_{0.05;9}=0.000000002$) presented in Table 6, it’s seen that there were statistically significant differences between the thickness swelling of multiday hot press boards and continuous hot press boards. The thickness swelling of both boards was not homogeneous. However, multiday hot press boards swelled much more than continuous hot press boards. Therefore, 37% increase in swelling may become meaningful due to the absorbance tendency of the multiday hot press boards as seen in moisture properties.

**Table 6**: Statistics for swelling in the thickness of 24 hours properties of particleboards.

<table>
<thead>
<tr>
<th>Test of Boards</th>
<th>Groups</th>
<th>N</th>
<th>Average</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>$t$ (95% CI*)</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swelling in Thickness 24 hours (%)</td>
<td>MHP particleboards</td>
<td>10</td>
<td>16.95</td>
<td>0.92</td>
<td>0.29</td>
<td>21.65</td>
<td>9</td>
<td>0.000000002</td>
</tr>
<tr>
<td></td>
<td>CHP particleboards</td>
<td>10</td>
<td>10.61</td>
<td>0.14</td>
<td>0.04</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Confidence Interval, N: Number of samples, $t$: the computed test statistic, df: the degrees of freedom, p values: confidence level for a confidence interval, multiday hot press (MHP), continuous hot press (CHP).
According to the t-test results ($t_{0.05:18}=0.00000000000000000000001$) presented in Table 7, there were no statistically significant differences between the water absorption of multiday hot press boards and continuous hot press boards. The water absorption of both boards was homogeneous. Therefore, 39.9% increase in water absorption may not become meaningful due to the absorbance tendency of the multiday hot press boards as seen in absorption properties. According to Nemli et al. (2004) measured the 24 hours water absorption of particleboard single day press values higher than the continuous press.

Table 7: Statistics for water absorption 24 hours properties of boards.

<table>
<thead>
<tr>
<th>Test of Boards</th>
<th>Groups</th>
<th>N</th>
<th>Average</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>t (95% CI*)</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Absorption 24 hours (%)</td>
<td>MHP particleboards</td>
<td>10</td>
<td>81.31</td>
<td>0.84</td>
<td>0.27</td>
<td>72.37</td>
<td>18</td>
<td>0.00000000000000000000001</td>
</tr>
<tr>
<td></td>
<td>CHP particleboards</td>
<td>10</td>
<td>58.13</td>
<td>0.56</td>
<td>0.18</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Confidence Interval, N: Number of samples, t: the computed test statistic, df: the degrees of freedom, p values: confidence level for a confidence interval, multiday hot press (MHP), continous hot press (CHP).
Mechanical Tests

The mechanical test results as a diagram of particleboard were presented in Fig. 5.

Bending strength

According to the t-test results ($t_{0,05:18}=0.747$) presented in Table 8, there were no statistically significant differences between the bending strength of multiday hot press boards and continuous hot press boards. The bending strength of both boards was homogeneous. Consequently, 1.27% increase in provided that bending strength of the multiday hot press boards than continuous hot press boards as seen in bending properties.

According to Nemli et al. (2004) study the elasticity modulus of particleboard made test which is single day press 2134.57 N/mm² and continuous press 1824.53 N/mm². The elasticity of the single-layer pressboards was measured higher. Nemli et al. (2004) test results of the study have supported this study.
According to the t-test results ($t_{0.05:18}=0.004$) presented in Table 9, there were no statistically significant differences between the modulus of elasticity of the multiday hot press boards and continuous hot press boards. The modulus of elasticity of both boards was homogeneous. The modulus of elasticity the multiday press particleboards was 11.35% more flexibility than the continuous press particleboards. Consequently, 11.35% increase in provided that bending strength of the multiday hot press boards than continuous hot press boards as seen in bending properties.

**Table 8**: Statistics for bending strength properties of boards.

<table>
<thead>
<tr>
<th>Test of Boards</th>
<th>Groups</th>
<th>N</th>
<th>Average</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>t (95 % CI*)</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bending Strength (N/mm²)</td>
<td>MHP particleboards</td>
<td>10</td>
<td>14.38</td>
<td>1.02</td>
<td>0.32</td>
<td>0.33</td>
<td>18</td>
<td>0.747</td>
</tr>
<tr>
<td></td>
<td>CHP particleboards</td>
<td>10</td>
<td>14.20</td>
<td>1.42</td>
<td>0.45</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Confidence Interval, N: Number of samples, t: the computed test statistic, df: the degrees of freedom, p values: confidence level for a confidence interval, multiday hot press (MHP), continuous hot press (CHP).

**Internal bond**

According to the t-test results ($t_{0.05:18}=0.176$) presented in Table 10, there were no statistically significant differences between the internal bond of multiday hot press boards and continuous hot press boards. The internal bond of both boards was homogeneous. The internal bond of the multiday press particleboards was 7.22% higher than the continuous press particleboards. Consequently, 7.22% increase in provided that

**Table 9**: Statistics for modulus of elasticity properties of boards.

<table>
<thead>
<tr>
<th>Test of Boards</th>
<th>Groups</th>
<th>N</th>
<th>Average</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>t (95 % CI*)</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulus of Elasticity (N/mm²)</td>
<td>MHP particleboards</td>
<td>10</td>
<td>2908.40</td>
<td>177.43</td>
<td>56.11</td>
<td>3.33</td>
<td>18</td>
<td>0.004</td>
</tr>
<tr>
<td></td>
<td>CHP particleboards</td>
<td>10</td>
<td>2612.00</td>
<td>218.80</td>
<td>69.19</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Confidence Interval, N: Number of samples, t: the computed test statistic, df: the degrees of freedom, p values: confidence level for a confidence interval, multiday hot press (MHP), continuous hot press (CHP).
internal bond of the multiday hot press boards than continuous hot press boards as seen
in internal bond breakage properties. Ferrandez-Villena et al. (2020) have explained that
mechanical properties are amplified with the increase in pressing time (7, 7+7, 15, 15+15
min) whereas shorter pressing time caused better physical property values.

Table 10: Statistics for internal bond properties of boards.

<table>
<thead>
<tr>
<th>Test of Boards (N/mm²)</th>
<th>Groups</th>
<th>N</th>
<th>Average</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>t (95% CI*)</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal Bond</td>
<td>MHP particleboards</td>
<td>10</td>
<td>0.401</td>
<td>0.050</td>
<td>0.016</td>
<td>1.407</td>
<td>18</td>
<td>0.176</td>
</tr>
<tr>
<td></td>
<td>CHP particleboards</td>
<td>10</td>
<td>0.374</td>
<td>0.034</td>
<td>0.011</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Confidence Interval, N: Number of samples, t: the computed test statistic, df: the degrees of freedom, p values: confidence level for a confidence interval, multiday hot press (MHP), continuous hot press (CHP).

Surface soundness

According to the t-test results (t 0.05:18=0.000007) presented in Table 11, there
were no statistically significant differences between the surface soundness of multiday
hot press boards and continuous hot press boards. The surface soundness of both boards
was homogeneous. The surface soundness of the continuous press particleboards was a
percentage 18.81 % higher than the multiday press particleboards. However, the
percentage 18.81 % increased on surface soundness of the continuous hot press boards
than multiday hot press boards.

Table 11: Statistics for surface soundness properties of boards.

<table>
<thead>
<tr>
<th>Test of Boards (N/mm²)</th>
<th>Groups</th>
<th>N</th>
<th>Average</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>t (95% CI*)</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Soundness</td>
<td>MHP particleboards</td>
<td>10</td>
<td>1.127</td>
<td>0.078</td>
<td>0.025</td>
<td>-6.270</td>
<td>18</td>
<td>0.000007</td>
</tr>
<tr>
<td></td>
<td>CHP particleboards</td>
<td>10</td>
<td>1.339</td>
<td>0.073</td>
<td>0.023</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Confidence Interval, N: Number of samples, t: the computed test statistic, df: the degrees of freedom, p values: confidence level for a confidence interval, multiday hot press (MHP), continuous hot press (CHP).

Withdrawal of screw resistance

According to the t-test results (t 0.05:9.57=0.0418) presented in Table 12, there
were statistically significant differences between the withdrawal of screw resistance of
multiday hot press boards and continuous hot press boards. The withdrawal of screw resistance of both boards was not measured as homogeneous. The reason was that the working principles of the multiday hot press from the continuous hot press and the features of the hot press were different from each other. The withdrawal of screw resistance of the continuous press particleboards was percentage 14 % higher than the multiday press particleboards. Consequently, the percentage 18,81 % increased on surface soundness of the continuous hot press boards than multiday hot press boards.

Table 12: Statistics for withdrawal of screw resistance properties of boards.

<table>
<thead>
<tr>
<th>Test of Boards</th>
<th>Groups</th>
<th>N</th>
<th>Average</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>t (95 % CI*)</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Withdrawal of Screw Resistance (N/mm²)</td>
<td>MHP particleboards</td>
<td>10</td>
<td>74,64</td>
<td>13,86</td>
<td>4,38</td>
<td>-2,349</td>
<td>9,57</td>
<td>0,0418</td>
</tr>
<tr>
<td></td>
<td>CHP particleboards</td>
<td>10</td>
<td>85,10</td>
<td>2,47</td>
<td>0,78</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Confidence Interval, N: Number of samples, t: the computed test statistic, df: the degrees of freedom, p values: confidence level for a confidence interval, multiday hot press (MHP), continous hot press (CHP).

According to Güler and Sancar (2016) assessed that the single-storey press particleboards and continuous press particleboards of mechanical properties (bending strength, modulus of elasticity, internal bond) of all test results compared and the single storey press boards mechanical properties resulted in more quality than continuous press boards properties.

According to Figure 5 results, the mechanical properties (bending strength, modulus of elasticity, internal bond) of particleboards have resulted in more quality multiday press particleboards than continuous press boards properties. However, the continuous press particleboards of mechanical properties (surface soundness, withdrawal of screw resistance) higher measured than multiday press particleboard. Güler and Sancar (2016) test results of the mechanical properties (bending strength, modulus of elasticity, internal bond) of particleboards were supported test results in this study. Camlibel (2021)
showed in his study that according to multiday layer hot press parameters which were the increase in pressing time and a decrease in press temperature and press speed; as a result of testing the produced boards the internal bond, modulus of elasticity, screw holding strength increased, but the flexural strength and surface resistance of the board decreased.

**Figure 5:** Mechanical test groups of particleboards.

<table>
<thead>
<tr>
<th>Mechanical Test Groups</th>
<th>Multiday-hot press particleboard</th>
<th>Continuous hot press particleboard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bending strength</td>
<td>14.38</td>
<td>14.20</td>
</tr>
<tr>
<td>Modulus of elasticity</td>
<td>2988.40</td>
<td>2612.00</td>
</tr>
<tr>
<td>Internal bond</td>
<td>0.40</td>
<td>0.37</td>
</tr>
<tr>
<td>Surface soundness</td>
<td>14.20</td>
<td>13.38</td>
</tr>
<tr>
<td>Withdrawal of screw resistance</td>
<td>74.64</td>
<td>85.10</td>
</tr>
</tbody>
</table>

**Formaldehyde gas emission**

The Formaldehyde content emission results as a diagram of particleboard were presented in Fig. 6. According to the t-test results (t 0.05:18=0,00000000000000000002) presented in Table 13, there were no statistically significant differences between the formaldehyde gas emissions of multiday hot press particleboards and continuous hot press particleboards. The formaldehyde gas emissions of both boards were homogeneous. Consequently, there are differences (p < 0.05) between the groups. As shown in Table 13, continuous hot press particleboards production provided a significant reduction (57.12 %) in formaldehyde gas emission when compared to multiday hot press
particleboards result. Therefore, the utilization of continuous hot press production not only contributes to the reduction of gas emission but also health more than the multiday hot press. A remarkable decrease (57,12) in formaldehyde emission was observed when particleboard production using to continuous hot press. Camlibel (2020) performed that carried out his work in a panel production continuous press pross in the factory. According to the assess results, the biggest formaldehyde content emission performed 0,98 mole UF resin while the lowest values 0,88 moles resin. According to Hong et al. (2017) assessed the study’s results, formaldehyde content emission of the MDF boards decreased and increased with the increase in density and adhesive content (from 8 % to 14 %), respectively.

Table 13: Statistics for formaldehyde content properties of boards.

<table>
<thead>
<tr>
<th>Test of Boards</th>
<th>Groups</th>
<th>N</th>
<th>Average</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>t (95 % CI*)</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formaldehyde Content (mg / 100 g)</td>
<td>MHP particleboards</td>
<td>10</td>
<td>5.763</td>
<td>0.143</td>
<td>0.045</td>
<td>37.062</td>
<td>18</td>
<td>0.000000000000000002</td>
</tr>
<tr>
<td></td>
<td>CHP particleboards</td>
<td>10</td>
<td>3.668</td>
<td>0.107</td>
<td>0.034</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Confidence Interval, N: Number of samples, t: the computed test statistic, df: the degrees of freedom, p values: confidence level for a confidence interval, multiday hot press (MHP), continous hot press (CHP).

Figure 6: Formaldehyde gas emission test groups.
According to figure 6 results, formaldehyde gas emission analysis less measured the continuous press particleboards (3.67 mg / 100 g) than multiday press particleboard (5.76 mg / 100 g). Camlibel and Ayata (2021) according to this study as a result of the increase in the mole amount of urea-formaldehyde glue, the free formaldehyde emission in the high-density fiberboard (HDF) increased. The free formaldehyde analysis result of high-density fiberboard (HDF) produced with 0.88 moles urea-formaldehyde glue; 7.40 mg / 100 g measured. The free formaldehyde analysis result of high-density fiberboard (HDF) produced with 1.17 moles urea-formaldehyde glue; 14.76 (mg / 100 g) measured. Camlibel and Aydin (2022) explained that according to the results of the studies performed on unconditioned and conditioned particle boards, the most obvious parameter affected by the increase in continuous press speed was free formaldehyde.

CONCLUSIONS

The influence of the multiday hot press and continuous hot press on the physical and mechanical properties, and formaldehyde gas emission content of the particleboards were investigated in this study. It is shown that thickness, density, moisture content were not an important increase in both research particleboards. The thickness swelling percentage 37 % and water absorption percentage 40 % test measurement results of multiday hot press boards have increased significantly compared to the test measurement results of continuous hot press boards. It is seen that thickness swelling and water absorption were increased in the multiday hot press of particleboards.

Internal bond percentage 7.22 %, bending elasticity percentage 1.27 % and modulus of elasticity percentage 11.35 % are increased in multiday hot press particleboards than continuous hot press particleboards. But continuous hot press particleboards are increased surface soundness percentage 18.81 % and withdrawal of
screw resistance percentage 14 %. The remarkable increase in surface soundness and withdrawal of screw resistance was observed when particleboard production using to continuous hot press.

The remarkable decreased formaldehyde content was analysed when using continuous hot press than multiday hot press particleboards test results. In the result of working was a decreased percentage of 57,12 %. According to the formaldehyde emission analysis results, it is seen that low analysis of formaldehyde emission is very important to use continuous presses in particleboard manufacture.

ACKNOWLEDGMENTS

The authors would like to thank Enus KOC and the director of the Kastamonu Integrated Wood Inc.

REFERENCES


Godbille, F.D. 2002. *A simulation model for the hot pressing of particleboard*. The University of New Brunswick, Canada.


