ISSN impresa 0717-3644
ISSN online 0718-221X

Maderas. Ciencia y tecnología 2023 (25): 7, 1-14

DOI: 10.4067/s0718-221x2023000100407

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

Osman Camlibel[1,♠]

https://orcid.org/0000-0002-8766-1316

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 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. 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.

[1]Kırıkkale University. Kırıkkale Vocational School. Interior Design. Kırıkkale, Turkey.
♠Corresponding author: osmancamlibel@kku.edu.tr
Received: 07.02.2021 Accepted: 10.11.2022

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, 680 kg/m³ 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 ºC 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 ºC, 180 ºC, 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 by both single storey press and continuous press and the produced particleboards are tested of technological properties. According to test results, single-storey presses 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.

Solid matter (%)	Mole ratio (U/F)	Density (g/cm³)	Viscosity-second (25 ºC cps)	Gel time-second (100 °C) (20 % (NH4)$_2$SO$_4$)	pH	Free Formaldehyde (%)	Metilol groups (%)	Shelf time (day)
62 ± 1	1,07	1,227	20 -35	30 - 65	7-8,2	0,2	12 -15	75

cps: centipoise

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 1227 kg/m³ and 6,4, 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; 960 kg/m³.

Production parameters

Hardwood (60 %) and softwood (40 %) were used particleboard production at the kind of materials. Mixture chips of the scoth 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 ures formaldehyde resin, 20 % ammonium sulfate as solution and 950 kg/m³ 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 2: Production parameters of particleboard.

Parameters	Multiday Press	Continous Press
Softwood (Scoth pine) (%)	30	30
Hardwood (Oak) (%)	40	40
Hardwood (Beech) (%)	20	20
Softwood (Poplar tree cover) (%)	10	10
Resin (F:U) moles ratio	1,07	1,07
Resin solid (%)	62	62
Resin solid according to dry chips (%)	SL:13; CL:7	SL:10,8; CL:6
Hardener according to resin solid ratio (%)	SL:3,25; CL:4,9	SL:2,7; CL:4,2
Paraffin according to dry chips (%)	SL:0,28; CL:0,35	SL:0,24; CL:0,30
Chips moisture (%)	SL:14,5; CL:5,5	SL:14,88; CL:5,90
Press temperature (ºC)	183	210
Press speed (mm/s)	200	580
Press time (s)	200	85

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 (Pallmann 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

Figure 2 of this study was presented both the multiday hot press (Figure 1) and continuous press (continuous hot press).

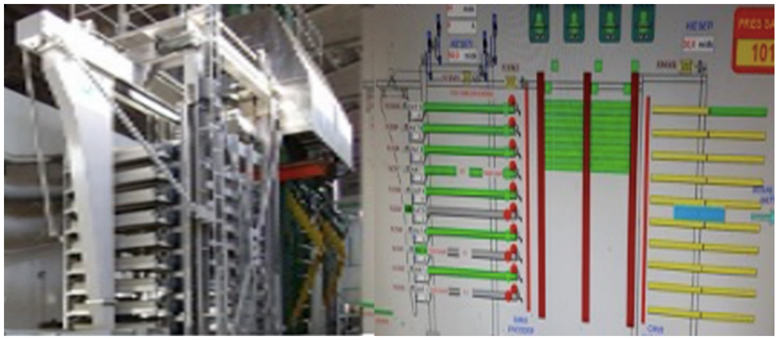

Figure 1: Multiday hot press.

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 ºC ± 2 ºC and 65 % ± 5 % relative humidity according to ISO 554 (1976). Particleborads 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 (1999), TS EN 323 (1999), TS EN 322 (1999) and TS EN 317 (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 310 (1999), TS EN 319 (1999), and TS EN 311 (2005) standards, respectively.

Formaldehyde content analysis

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

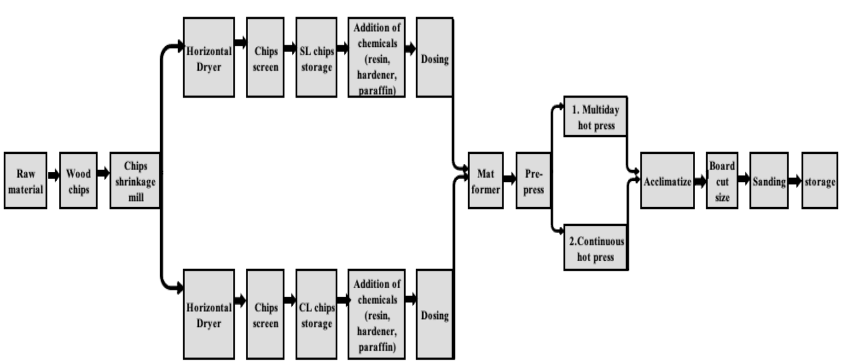

Figure 2: Workflow diagram of the test samples production.

RESULTS AND DISCUSSION

Physical tests

The physical test results as a diagram of particleboard were presented in Figure 3.

Thickness

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.

Test of Boards	Groups	N	Average	Std. Deviation	Std. Error Mean	t (95 % CI*)	df	p
Thickness (mm)	MHP particleboards	10	17,995	0,018	0,006	11,438	18	0,000000001
	CHP particleboards	10	17,881	0,026	0,008			

*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).

Density

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.

Test of Boards	Groups	N	Average	Standard Deviation	Std. Error Mean	t (95 % CI*)	df	p
Density (kg/m^3)	MHP particleboards	10	616,29	16,74	5,29	-3,007	18	0,0076
	CHP particleboards	10	633,38	6,53	2,07			

*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).

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.

Test of Boards	Groups	N	Average	Std. Deviation	Std. Error Mean	t (95 % CI*)	df	p
Moisture Content (%)	MHP particleboards	10	6,440	0,207	0,065	0,335	18	0,742
	CHP particleboards	10	6,410	0,194	0,061			

*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).

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.

Test of Boards	Groups	N	Average	Std. Deviation	Std. Error Mean	t (95% CI*)	df	p
Swelling in Thickness 24 hours (%)	MHP particleboards	10	16,95	0,92	0,29	21,65	9	0,000000002
	CHP particleboards	10	10,61	0,14	0,04			

*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).

Water absorption

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.

Test of Boards	Groups	N	Average	Std. Deviation	Std. Error Mean	t (95 % CI*)	df	p
Water Absorption 24 hours (%)	MHP particleboards	10	81,31	0,84	0,27	72,37	18	0,00000000000000000000001
	CHP particleboards	10	58,13	0,56	0,18			

*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 Figure 3 results, the physical properties of particleboards have resulted in more quality continuous press boards than multiday press boards properties. The continuous press particleboards of physical properties (thickness swelling, water absorptions) less measured than multiday press particleboard.

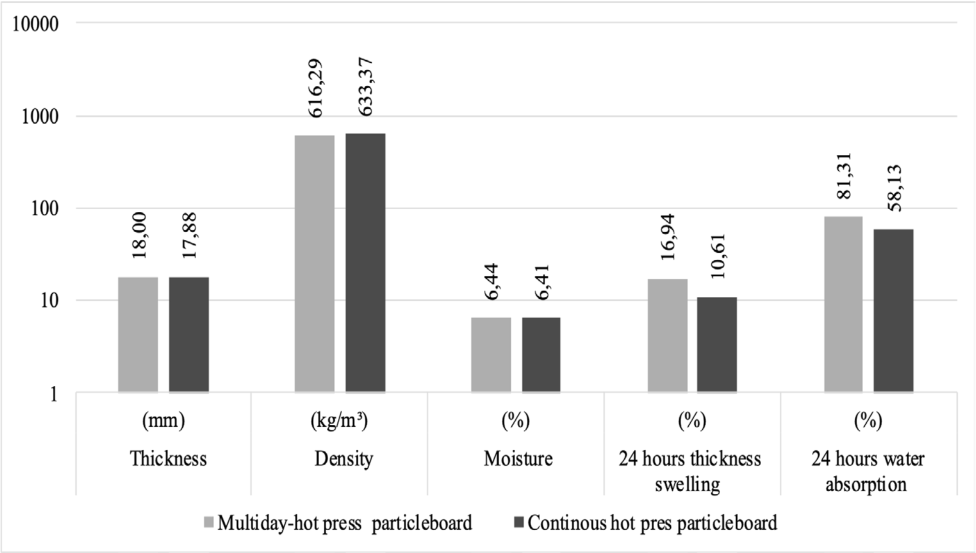

Figure 3: Physical test groups of particleboards.

Mechanical tests

The mechanical test results as a diagram of particleboard were presented in Figure 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 MPa and continuous press 1824,53 MPa. The elasticity of the single-layer pressboards was measured higher. Nemli *et al.* (2004) test results of the study have supported this study.

Table 8: Statistics for bending strength properties of boards.

Test of Boards	Groups	N	Average	Std. Deviation	Std. Error Mean	t (95 % CI*)	df	p
Bending Strength (N/mm^2)	MHP particleboards	10	14,38	1,02	0,32	0,33	18	0,747
	CHP particleboards	10	14,20	1,42	0,45			

*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).

Modulus of elasticity

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 9: Statistics for modulus of elasticity properties of boards.

Test of Boards	Groups	N	Average	Std. Deviation	Std. Error Mean	t (95 % CI*)	df	p
Modulus of Elasticity (N/mm²)	MHP particleboards	10	2908,40	177,43	56,11	3,33	18	0,004
	CHP particleboards	10	2612,00	218,80	69,19			

*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).

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 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.

Test of Boards	Groups	N	Average	Std. Deviation	Std. Error Mean	t (95 % CI*)	df	p
Internal Bond (N/mm²)	MHP particleboards	10	0,401	0,050	0,016	1,407	18	0,176
	CHP particleboards	10	0,374	0,034	0,011			

*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).

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.

Test of Boards	Groups	N	Average	Std. Deviation	Std. Error Mean	t (95 % CI*)	df	p
Surface Soundness (N/mm²)	MHP particleboards	10	1,127	0,078	0,025	-6,270	18	0,000007
	CHP particleboards	10	1,339	0,073	0,023			

*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).

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.

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

*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 4 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.

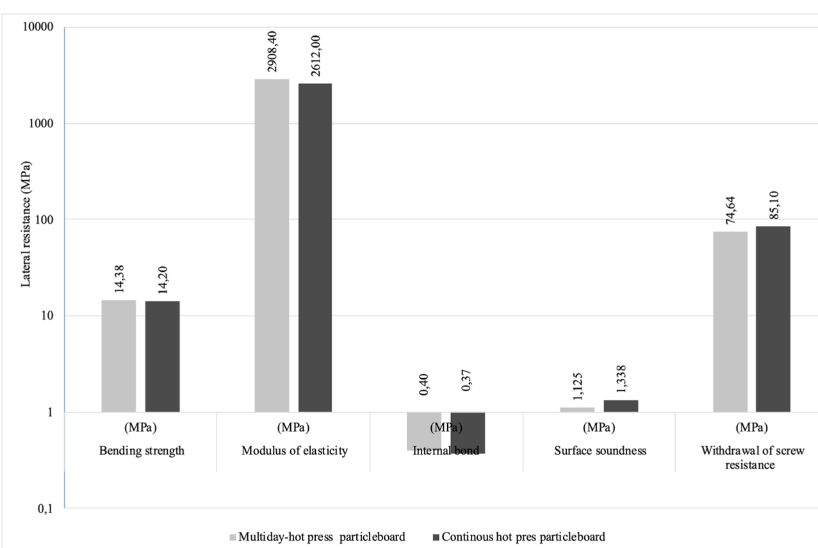

Figure 4: Mechanical test groups of particleboards.

Formaldehyde gas emission

The Formaldehyde content emission results as a diagram of particleboard were presented in Figure 5. According to the t-test results (t 0,05:18=0,00000000000000002) 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.

Test of Boards	Groups	N	Average	Std. Deviation	Std. Error Mean	t (95 % CI*)	df	p
Formaldehyde Content (mg / 100 g)	MHP particleboards	10	5,763	0,143	0,045	37,062	18	0,00000000000000002
	CHP particleboards	10	3,668	0,107	0,034			

*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).

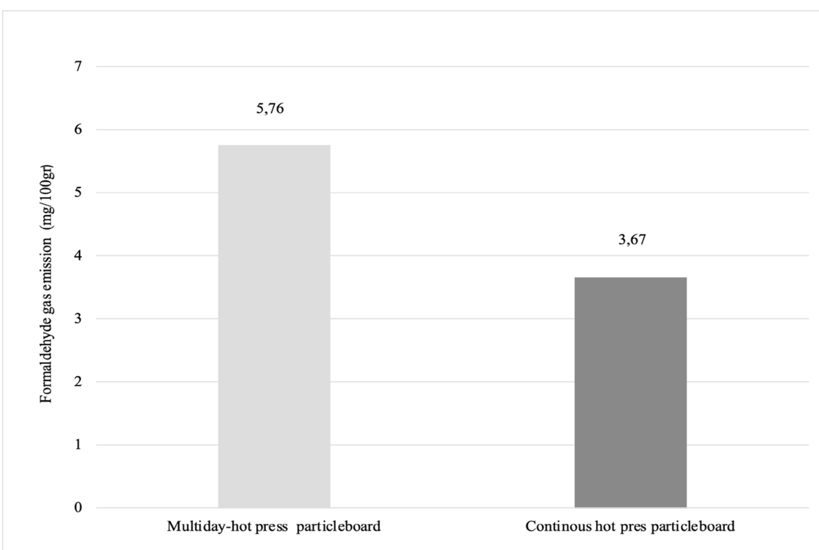

Figure 5: Formaldehyde gas emission test groups.

According to Figure 5 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 Aydın (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.

CONCLUSİONS

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

Arruda, L.M.; Del Menezzı, C.H.S.; Teıxeıra, D.E.; De Araujo, P.C. 2011. Lignocellulosic composites from Brazilian giant bamboo (*Guadua magna*) Part 1: Properties of resin bonded particleboards. *Maderas. Ciencia y Tecnologia* 13(1): 49-58. http://dx.doi.org/10.4067/S0718-221X2011000100005

Barragan-Lucas, A.D.; Llerena-Miranda, C.; Quijano-Avilés, M.; Chóez-Guaranda, I.A.; Maldonado-Guerrero, L.C.; Manzano-Santana, P.I. 2019. Effect of resin content and pressing temperature on banana pseudostem particle boards properties using full factorial design. *Anais da Academia Brasileira de Ciências* 91: e20180302. https://doi.org/10.1590/0001-3765201920180302

Candan, Z.; Akbulut, T.; Wang, S.; Zhang, X.; Faruk Sisci, A. 2012. Layer thickness swell characteristics of medium density fibreboard (MDF) panels affected by some production parameters. *Wood Research* 57(3): 441-452. http://www.woodresearch.sk/wr/201203/10.pdf

Camlibel, O. 2020. Sıcak pres parametrelerinin yonga levhanın fiziksel özellikleri ve formaldehit emisyonuna etkisi. *Artvin Çoruh Üniversitesi Orman Fakültesi Dergisi* 21(2): 276-283. https://doi.org/10.17474/artvinofd.740136

Camlibel, O.; Aydın, M. 2022. The effects of continuous press speed and conditioning time on the particleboard properties at industrial scale. *BioResources* 17(1): 159-176. https://bioresources.cnr.ncsu.edu/resources/the-effects-of-continuous-press-speed-and-conditioning-time-on-the-particleboard-properties-at-industrial-scale/

Camlibel, O. 2021. The Effect of Multi-Layer Press Parameters on Mechanical Properties in Particleboard Production. *Türk Tarım ve Doğa Bilimleri Dergisi* 8(3): 800-807. https://doi.org/10.30910/turkjans.870258

Camlibel, O.; Ayata, U. 2021. The Effect of Mole Ratio on Some Physical, Mechanical and Formaldehyde Emissions in High-Density Fibreboards (HDF). Night Library Publishing House, 335pp.

Ciobanu, V.D.; Zeleniuc, O.; Dumitrascu, A.; Lepadatescu, B.; Iancu, B. 2014. The influence of speed and press factor on oriented strand board performance in continuous press. *BioResources* 9(4): 6805-6816. https://bioresources.cnr.ncsu.edu/resources/the-influence-of-speed-and-press-factor-on-oriented-strand-board-performance-in-continuous-press/

Ciobanu, V.D.; Zeleniuc, O.; Dumitrascu, A.E.; Lepadatescu, B.; Iancu, B. 2014. The influence of speed and press factor on oriented strand board performance in continuous press. *BioResources* 9(4): 6805-6816. https://bioresources.cnr.ncsu.edu/wp-content/uploads/2016/06/BioRes_09_4_6805_Ciobanu_ZSLI_Oriented_Strand_Bd_Perform_Speed_Continuous_Press_6110.pdf

Evessen, H.S. 1984. Continuous pressing processes in particleboard production-The Küsters press-process. *Holz als Roh und Werkstoff* 42(2): 63-66. https://agris.fao.org/agris-search/search.do?recordID=XE844TB76

Ferrandez-Villena, M.; Ferrandez-Garcia, C.E.; Garcia-Ortuño, T.; Ferrandez-Garcia, A.; Ferrandez-Garcia, M.T. 2020. The influence of processing and particle size on binderless particleboards made from *Arundo donax* L. Rhizome. *Polymers* 12(3): e696. https://doi.org/10.3390/polym12030696

Funk, M.; Wimmer, R.; Adamopoulos, S. 2017. Diatomaceous earth as an inorganic additive to reduce formaldehyde emissions from particleboards. *Wood Material Science & Engineering* 12(2): 92-97. https://doi.org/10.1080/17480272.2015.1040066

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

Güler, C.; Sancar, S. 2016. Yonga levha Fabrikasının Çalışma Prensibi ve Farklı Presleme Tekniğinin Levha Kalitesi Üzerine Etkisi. *Ormancılık Dergisi* 12(1): 1-10. http://ordergi.duzce.edu.tr/Dokumanlar/arsiv/2016_1_Tam.pdf

Hong, M.K.; Lubis, M.A.R.; Park, B.D. 2017. Effect of panel density and resin content on properties of medium-density fiberboard. *Journal of the Korean Wood Science and Technology* 45(4): 444-455. https://doi.org/10.5658/WOOD.2017.45.4.444

Iswanto, A.; Febrianto, F.; Hadi, Y.; Ruhendi, S.; Hermawan, D. 2013. The Effect of Pressing Temperature and Time on the Quality of Particle Board Made from Jatropha Fruit Hulls Treated in Acidic Condition. *Makara Joural of Technology* 17(3): 145-151. https://doi.org/10.7454/mst.v17i3.2930

Istek, A.; Özlüsoylu, İ.; Onat, M.S.; Özlüsoylu, Ş. 2018. Formaldehyde Emission Problems and Solution Recommendations on Wood-Based Boards Formaldehyde Emission Problems and Solution Recommendations on Wood-Based Boards: A review. *Journal of Bartin Faculty of Forestry* 20(2): 382-387. https://dergipark.org.tr/en/pub/barofd/issue/36468/425409

Kord, B.; Roohani, M.; Kord, B. 2015. Characterizatıon and utilizatıon of reed stem as a lignocellulosic resource for particleboard productıon. *Maderas. Ciencia y Tecnologia* 17(3): 517- 524. http://dx.doi.org/10.4067/S0718-221X2015005000046.

Lv, Y.; Liu, Y.; Jing, W.; Woźniak, M.; Damaševičius, R.; Scherer, R.; Wei, W. 2020. Quality control of the continuous hot-pressing process of medium density fiberboard using fuzzy failure mode and effects analysis. *Applied Sciences* 10(13): e4627. https://doi.org/10.3390/app10134627

Maraghi, M.M.R.; Tabei, A.; Madanipoor, M. 2018. Effect of board density, resin percentage and pressing temperature on particleboard properties made from mixing of poplar wood slab, citrus branches and twigs of Beech. *Wood Research* 63(4): 669-682. http://www.woodresearch.sk/wr/201804/12.pdf.

Nemli, G. 2002. Factors affecting the production of E1 type particleboard. *Turkish Journal of Agriculture and Forestry* 26(1): 31-36. https://dergipark.org.tr/en/download/article-file/120105

Nemli, G.; Kalaycıoğlu, H.; Akbulut, T. 2004. Influence of press type on the technological properties of particleboard. *Artvin Çoruh Üniversitesi Orman Fakültesi Dergisi* 5(1): 89-95. http://ofd.artvin.edu.tr/tr/pub/issue/2253/29691.

Nitu, I.P.; Islam, Md.; Ashaduzzaman, Md.; Amin, Md.K.; Shams, Md.I. 2020. Optimization of processing parameters for the manufacturing of jute stick binderless particleboard. *Journal of Wood Science* 66: e65. https://doi.org/10.1186/s10086-020-01913-z

Saad, A.; Kasim, A.; Gunawarman, S. 2019. Optimization of Composition, Temperature and Time on Production of Particle Board Made from Pine Bark and EFB. IOP Conference Series. *Earth and Environmental Science* 327: e012015. https://iopscience.iop.org/article/10.1088/1755-1315/327/1/012015

Sarı, B.; Nemli, G.; Baharoğlu, M.; Bardak, S.; Zekoviç, E. 2012. The role of solid content of adhesive and panel density on the dimensional stability and mechanical properties of particleboard. *Journal of Composite Materials* 47(10): 1247-1255. https://doi.org/10.1177/0021998312446503

Shupin, L.; Li, G.; Wenjing, G. 2020. Effect of expanded polystyrene content and press temperature on the properties of low-density wood particleboard. *Maderas. Ciencia y Tecnologia* 22(4): 549-558. http://dx.doi.org/10.4067/S0718-221X2020005000413

Solt, P.; Konnerth, J.; Gindl-Altmutter, W.; Kantner, W.; Moser, J.; Mitter, R.; Van Herwijnen, H.W.G. 2019. Technological performance of formaldehyde-free adhesive alternatives for particleboard industry. *International Journal of Adhesion and Adhesives* 94: 99-131. https://doi.org/10.1016/j.ijadhadh.2019.04.007

Thoemen, H.; Humphrey, P.E. 2003. Modeling the continuous pressing process for wood-based composites. *Wood and Fiber Science* 35(3): 456-468. https://wfs.swst.org/index.php/wfs/article/view/827

TS. 1999. Wood based panels density specifications. TS EN 323.1999. TSE. Ankara, Turkey.

TS. 1999. Wood- Based panels- Determination of dimensions of boards- Part 1: Determination of thickness, width and length. TS EN 324-1, 1999. TSE. Ankara, Turkey.

TS. 1999. Wood-based panels- Determination of moisture content. TS EN 322. 1999. TSE. Ankara, Turkey.

TS. 1999. Particleboards and fibreboards- Determination of swelling in thickness after immersion in water. TS EN 317. 1999. TSE. Ankara, Turkey.

TS. 1999. Wood- Based panels- Determination of modulus of elasticity in bending and of bending strength. TS EN 310. 1999. TSE. Ankara, Turkey.

TS. 1999. Particleboards and fibreboards- determination of tensile strength perpendicular to the plane of the board. TS EN 319. 1999. TSE. Ankara, Turkey.

TS. 2005. Wood-based panels - Surface soundness- Test method. TS EN 311. 2005. TSE. Ankara, Turkey.

TS. 1999. Wood based panels- Determination of formaldehyde content- Extraction method called the perforator method. TS 4894 EN 120. 1999. TSE. Ankara, Turkey.

Yel, H.; Cavdar, A.D.; Torun, S.B. 2020. Effect of press temperature on some properties of cement bonded particleboard. *Maderas. Ciencia y Tecnologia* 22(1): 83-92. http://dx.doi.org/10.4067/S0718-221X2020005000108

Zhu, L.; Wang, Z.; Shao, X.; Liu, Y. 2018. Prescribed performance control for MDF continuous hot pressing hydraulic system. *International Journal of Modelling, Identification and Control* 29(3): 185. https://doi.org/10.1504/IJMIC.2018.091241