Drewno 2021, Vol. 64, No. 207
DOI: 10.12841/wood.1644-3985.342.05

İlknur Kumaş, Uğur Aras, Hülya Kalaycioğlu, Bedri Serdar, Hüsnü Yel

EFFECT OF GROWING ALTITUDE, PARTICLE DRYING TEMPERATURE AND PRESS TEMPERATURE ON SOME TECHNOLOGICAL PROPERTIES OF PARTICLEBOARD PRODUCED FROM BLACK ALDER WOOD

This study investigated the effects of the growing altitude, particle drying temperature and press temperature on some technological properties of particleboard produced from black alder wood. The particles were produced from wood taken from the KTÜ Campus and from Çamoba in Trabzon. Production and tests of the experimental particleboards were carried out at Kastamonu Integrated Wood Company. In production of the particleboards, wood from different growing altitudes [50 m and 250 m] was used, and different drying temperatures [120 and 150°C] and press temperatures [150 and 200°C] were applied. Mechanical, physical and anatomical properties of the produced boards were investigated. According to the results, the mechanical properties deteriorate when the altitude increases. Increasing the particle drying temperature and press temperature had a positive effect on dimensional stability. A high press temperature improved the mechanical properties of the boards. In addition, growing altitude had an effect on anatomical properties: when the altitude increased, the diameter of vessels narrowed, the number of vessels per mm^2 increased, and fiber length decreased. This resulted in a deterioration in mechanical properties at the higher altitude.

Keywords: black alder, drying temperature, press conditions, anatomical factors, growing altitude, physical and mechanical properties

İlknur Kumaş (*ilknur-kumas@hotmail.com*), Karadeniz Technical University, Faculty of Forestry, Department of Forest Industrial Engineering, Trabzon; Ugur Aras✉ (*uguraras.86@gmail.com*) Karadeniz Technical University, Arsin Vocational Junior College, Materials and Materials Machining Technologies, Furniture and Decoration, Trabzon, Turkey; Hulya Kalaycioglu (*khulya@gmail.com*), Karadeniz Technical University, Faculty of Forestry, Department of Forest Industrial Engineering, Trabzon; Bedri Serdar (*bserdar@ktu.edu.tr*), Karadeniz Technical University, Faculty of Forestry, Department of Forest Engineering, Trabzon; Husnu Yel (*yel33@hotmail.com*), Artvin Coruh University, Faculty of Forestry, Dept. of Forest Industrial Engineering, Artvin, Turkey

Introduction

Developing technology, population growth and various campaigns currently lead to high levels of consumption. However, the resources available for production are limited and insufficient to meet demand, and will be completely inadequate in the future. Solutions are being sought, such as ensuring the continuity of scarce resources and developing alternatives to these resources.

In the past, wooden products were manufactured using solid wood. However, today’s conditions require the utilization of whole trees, because of the excessive increase in demand and lack of high-quality wood raw materials. For this reason, wood-based composites have taken the place of materials made of solid wood. Wood-based panels include various engineered wood products such as particleboards, fiberboards, plywood, and OSB.

Particleboard is obtained using wood particles and lignocellulosic plants with synthetic adhesives, which are pressed under high temperature until adhesive curing is completed. It is widely used in all areas of life, including in bedroom sets, dining room sets, bathroom cabinets, kitchen cabinets, children's rooms, training grounds, fairgrounds, and libraries [Kord et al. 2016; Abdulkareem et al. 2017].

It is important to know the effects of factors of production on board properties in order to obtain a product that is suitable for its places of use. Many factors affect the characteristics of particleboard, including tree species, particle geometry, type and amount of adhesives, pressing conditions, and specific gravity [Nemli 1995; Masraf 2005]. Press temperature has a particularly significant effect on the quality of the board. The curing of adhesives cannot be completed when the press temperature is insufficient. On the other hand, the properties of boards can be adversely affected if they are pressed at a high temperature [Henriques et al. 2017; Nemli 2002]. When high temperature is applied to wood, its brittleness increases and its mechanical strength properties decrease. On the other hand, dimensional stability increases [Esteves and Pereira 2009; Korkut et al. 2015]. Dimensional change is an important problem especially in production using urea formaldehyde (UF) adhesive. Therefore, selection of the appropriate drying temperature is important for the board’s quality properties.

Additionally, wood properties vary among species, among trees of the same species and in different parts of the same tree. Genetic and environmental factors are very influential on the anatomical structure and technological properties of wood [Wodzicki 2001; Topaloğlu et al. 2016]. Previous studies have shown that growing altitude affects a variety of properties in wood, such as density, chemical composition [Dönmez et al. 2013; Kiaei et al. 2015], anatomical properties and physico-mechanical properties [Raskila et al. 2006; Kiaei 2012; Kaygın et al. 2017]. However, solid wood differs from composite materials, whose properties can be influenced by process control. There is not enough information in the literature about the effects of growing altitude on the technological properties of particleboard. Therefore, the aim of this study was to investigate the effect of growing altitude, particle drying temperature, and press temperature on the quality properties of particleboard.

Materials and methods

Material

Particles obtained from black alder wood (*Alnus glutinosa* subsp. barbata (C.A.Mey.) Yalt.) were used in the production of the experimental boards. The woods were obtained from two different growing altitudes: the KTU Campus (50 m) and the Central Çamoba region (250 m). The trees were aged 26 years and had a diameter of 30 cm. Two samples were used for each altitude, and only the stem wood was used. Kastamonu Integrated Wood Industry and Trade Co. supplied the UF adhesive, ammonium sulfate and paraffin used in production. The characteristics of the UF adhesive used are given in Table 1.

Table 1. Properties of UF adhesive used in particleboard production

	Surface layer	Core layer
Solids content (%)	45	65.02
Density (g/cm^3)	1.213	1.282
Viscosity (cps)	45	300
pH	8.25	8.31
Gelling time (sec)	46	37

Methods

Manufacture of boards

The black alder trunks to be used in production were cut into pieces of 2.5 cm thickness using a chipper after the removal of bark. The pieces were then were reduced to particles by means of a knife ring flaker. The particles with air-dry moisture were sieved as surface and core layers. The drying process was carried out in a Vötsch Industrietechnik VC3 4060 climate control cabinet with drying temperatures of 120 and 150°C. The particles were dried to 2% moisture content and kept in a moisture-free environment until use in production. In the next step, the UF adhesive was applied with a laboratory-type mixing machine (glue blender) to obtain a homogeneous particle–adhesive mixture. For the blending, UF adhesive was used in an amount of 11% in surface layers and 9% in core layers based on the oven-dry weight of the particles. As the adhesive hardener, a 25% ammonium sulfate solution was used, in an amount of 2% in surface layers and 3% in core layers based on the oven-dry weight of the particles.

Before paraffin application and after the adhesive solution was completely consumed, the closed system was opened and poured evenly onto the particles. Based on the dry particle weight, 0.4% and 0.3% paraffin was individually applied to the surface and core particles respectively. Glued particles were spread into hand-made molds with dimensions of 50 × 50 × 1.8 cm. The surface layer/core layer ratio was selected as 65%/35%. The target density of the board was 620 kg/m^3. Cold pressing was applied before hot pressing after mat formation. The boards were pressed under a pressure of 2.5 MPa, at 150 and 200°C. Three boards were produced in each group. After the hot-pressing process, the boards were conditioned at 20 ±2°C and 65 ±5% relative humidity to reach a moisture content of about 12%. The groups and production conditions for the boards are given in Table 2.

Table 2. Experimental design of particle board types

Board type	Growing area	Drying temperature (°C)	Press temperature (°C)
K_1	Campus (50 m)	120	150
K_2		150	150
K_3		120	200
K_4		150	200
$Ç_1$	Camoba (280 m)	120	150
$Ç_2$		150	150
$Ç_3$		120	200
$Ç_4$		150	200

Anatomical properties

The black alder trunks taken from the KTU Campus and Çamoba were cut at breast height (1.30 m) and pieces were cut with dimensions 1 × 1 × 1 cm. When the samples were being prepared, attention was paid to avoid knots, decay and reaction wood. Anatomical characteristics were measured for the following: vessels (tangential and radial diameters, number per mm^2), fibers (length, width, lumen width and wall thickness) and rays (height, width and number per mm). Firstly, the test specimens were boiled because of softness and air in the tissues. They were suspended in alcohol-glycerin-distilled water until cross-sectioning after boiling. A piece of phenic acid (C_5H_5OH) was added to the mixture against fungi effects [Merev 1998]. Afterwards, the samples were sectioned in three directions with a sliding microtome: transversal, radial, and tangential. The sections were washed with pure water and clarified in sodium hypochlorite for about 25-30 min before being neutralized with acetic acid for 1-2 min and washed again. They were kept in saffron for 10 min for coloring. The colored samples were placed in a 50% alcohol-water mixture, and the slices were prepared transversally, radially and tangentially in glycerin gel [Ives 2001].

The wood elements were subjected to maceration to measure vessel lengths, fiber lengths and fiber widths. For this purpose, the Schultze method, which is the most common method and causes the least damage to wood elements, was used. Data were obtained from 30 experimental measurements. The number of vessels per mm^2 and the number of rays per mm were determined with an Olympus BX 50 photo microscope and an image monitoring and analysis system. The radial and tangential diameters of the vessels were measured with a research microscope coupled with a Nikon E 100 device using 10× lenses, from the widest point based on the lumen. The vessel cell length was measured to include the tip of the cells with 10× lenses [Baas et al. 1988]. Measurements were made with a Nikon E 100 research microscope using 10× (ray height) and 40× (ray width) lenses. The lengths of the fibers were measured with a Nikon E 100 microscope using 4× lenses, and fiber width and lumen width were measured using 40× lenses. Moreover, density values of the black alder woods were determined according to the EN 323 standard for both elevations.

Physical and mechanical properties

Physical and mechanical properties including density (D), water absorption (WA) and thickness swelling (TS), modulus of rupture (MOR), modulus of elasticity (MOE), internal bond strength (IB) and screw withdrawal resistance (SW) were determined based on EN 323:1993, ASTM D1037:1998, EN 317:1993, EN 310:1993, EN 319:1993 and EN 320:1993, respectively. The results were evaluated based on EN 312:2005. Twenty test samples were prepared for each experiment.

Statistical analysis

One-way analysis of variance (ANOVA) was performed to assess the influence of the investigated properties on the quality characteristics of the samples, using SPSS 13.0. Significant differences were analyzed between the mean values of the board types using Duncan’s new multiple range tests.

Results and discussion

Anatomical properties

The anatomical properties of black alder wood are given in Table 3. According to the results of one-way ANOVA, it was determined that the effect of altitude on the Campus and Çamoba black alder wood vessels (tangential and radial diameters, length and number) and rays (height and number) was statistically significant. However, altitude had no effect on fiber length and width, lumen width, wall thickness, and ray width values ($p < 0.05$). Figure 1 shows the transverse (TS), radial longitudinal (RLS) and tangential (TL) views of the alder wood. Sarıbas and Yaman [2009] determined that the earlywood vessel diameters decrease with increasing altitude. With an increase of altitude, the diameter of the wood elements decreases [Bakhsi 2003; Kiaei and Samariha 2011]. It may be stated that the increase in altitude decreased the vessel tangential and radial diameters and increased the amount of vessels per unit. The anatomical characteristics of the alder wood samples were compatible with the literature [Usta et al. 2014].

Duncan's test showed that altitude did not have a significant effect on the solid density of black alder wood. Oven-dry densities of wood samples obtained from the campus and from Çamoba were found to be 0.513 g/cm^3 and 0.528 g/cm^3 respectively. This result was consistent with the results of previous studies [Kahveci 2012; Milch et al. 2016].

Table 3. Anatomical properties of alder woods

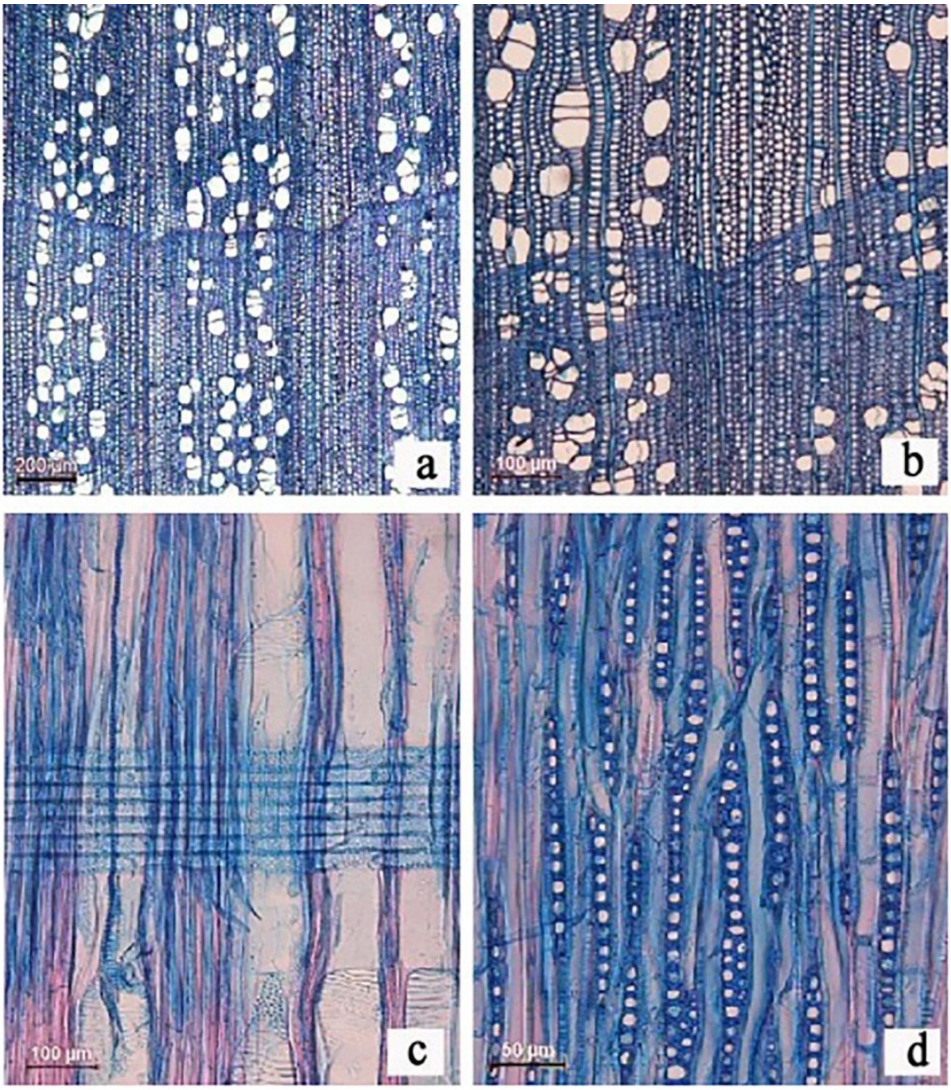
Anatomical properties		Sample area		
		N	Campus	Camoba
Vessels	Tangential diameter (µm)	60	58.5 ±7	55.5 ±7
	Radial diameter (µm)		80 ±10	75 ±9
	Number per mm^2		94 ±15	103 ±16
	Length (µm)		784.2 ±94.5	843.2 ±100.7
Fibers	Length (µm)		1296.3 ±174.8	1252.5 ±122.1
	Width (µm)		25.2 ±4.4	25.1 ±3.9
	Lumen width (µm)		14.8 ±2.8	14.8 ±3.3
	Cell wall thickness (µm)		5.2 ±1.6	5.2 ±1.1
Rays	Height		429 ±65	464 ±93
	Width		14 ±2	14 ±2
	Number per mm		15 ±2	14 ±2

The values after ± are standard deviation; S.D: $p > 0.05$; *: $p < 0.05$; **: $p < 0.01$; ns: not significant.

Physical and mechanical properties

Physical and mechanical properties are given in Table 4 for all board groups. It was shown that growing altitude did not affect the D values of the boards statistically. In addition, it was found that as the press temperature increased, there was a significant increase in the D values of the boards. Masraf [2005] reported that D values of the boards increased with an increase in press temperature and pressure. According to analysis of variance, growing altitude, particle drying temperature and press temperature had significant effects on the

WA and TS values of particleboard. Soaking in water for 24 h resulted in thickness swelling ranging from 27.62% to 20%.



a, b: TS, wood is diffuse porous, the growth ring is obvious, aggregate rays; c: RLS, homocellular rays, vessel, fiber texture, scalariform perforation table in vessel; d: TL, uniseriate-homogeneous rays, type III, fiber texture, and aggregate rays (gathered together).

Fig. 1. TS, RLS and TLS views of the wood of *Alnus glutinosa*

Table 4. The physical and mechanical properties of particleboards

	D (kg/m^3)	WA (%)	TS (%)	MOR (N/mm^2)	MOE (N/mm^2)	IB (N/mm^2)	SW (N/mm^2)
Low Alt							
120°C							
150°C	599^{A}	96.25^{E}	25.4^{D}	15.27^{B}	1860.92^{C}	0.82^{A}	949.83^{B}
	(1.1)*	(3.69)	(1.6)	(0.9)	(67)	(0.05)	(93.75)
200°C	611^{AB}	93.10^{D}	24.7^{D}	15.84^{A}	1871.17^{C}	0.88^{B}	797.08^{E}
	(2.0)	(4.04)	(1.5)	(0.51)	(194)	(0.05)	(110.12)
150°C							
150°C	604^{A}	90.10^{C}	23.2^{C}	14.73^{C}	1841.54^{C}	0.79^{C}	1037.80^{A}
	(1.1)	(2.81)	(0.9)	(1.2)	^{D} (158)	(0.07)	(95.73)
200°C	615^{C}	87.01^{B}	22.4^{C}	15.07^{BC}	1859.39^{C}	0.78^{C}	873.58^{C}
	(0.7)	(3.73)	(1.2)	(1.2)	(160)	(0.03)	(167)
High Alt							
120 °C							
150°C	591^{A}	94.26^{D}	24.8^{D}	13.06^{E}	1770.19^{D}	0.63^{D}	737.50^{F}
	(1.2)	(2.04)	(1.7)	(0.6)	(141)	(0.04)	(110.13)
200°C	599^{A}	91.65^{C}	20.8^{B}	15.38^{B}	2129.74^{A}	0.65^{D}	683.16^{G}
	(0.9)	(4.34)	(1.2)	(1.06)	(201)	(0.03)	(94.40)
150°C							
150°C	593^{A}	89.23^{B}	22.8^{C}	12.85^{F}	1759.30^{D}	0.58^{E}	746.50^{F}
	(1.8)	(2.90)	(1.7)	(0.79)	(93)	(0.03)	(98.49)
200°C	611^{AB}	85.37^{A}	19.9^{A}	14.1^{D}	2038.13^{B}	0.60^{E}	829.83^{D}
	(1.3)	(3.98)	(1.8)	(1.3)	(112)	(0.03)	(160.16)

The values after ± are standard deviations and the following letters show homogeneity groups ($p < 0.05$).

The TS results showed that the boards did not meet the requirements for TS stated in EN 312. With an increase in growing altitude, the WA values of all board groups decreased. Kiaei and Samariha [2011] determined that an increase in the altitude led to reduction of the diameter of wood elements and decreased volumetric swelling rates. Moreover, an increase in particle drying temperature led to a decrease in the WA and TS values of the boards.

The structure of the wood cell components was altered because of high temperature [Kartal et al. 2008; Li et al. 2017]. The degradation of hygroscopic components such as hemicelluloses and amorphous celluloses in the wood structure may have caused the increase in dimensional stability with increasing particle drying temperature [Sarı et al. 2013]. Additionally, with increasing press temperature, the WA and TS values of the boards decreased. Moisture, which is required to dissociate from the board, leaves the board quickly due to a high press temperature. The WA and TS values did not reach the same high level, because the wood material could not easily reach the initial moisture value due to hysteresis and cell deterioration in the particles [Noack et al. 1973; Patera et al. 2013].

Tree location (altitude), particle drying temperature and press temperature were found to have significant effects on the MOR, MOE, IB and SW values, according to analysis of variance. According to EN 312, a MOR value of 13 MPa and a MOE value of 1600 MPa are the minimum bending resistance requirements for type P2 particleboards used in dry conditions. Therefore, all of the boards except for groups Ç1, Ç3 and Ç4 met the bending resistance requirements. An increase in altitude led to a decrease in the bending resistance properties. The density values of wood samples taken from KTU Campus (50 m) and the Central Çamoba region (250 m) were found to be 0.548 and 0.568 g/cm^3 respectively. Kiaei [2012] reported that increased altitude led to an increase in wood density. The use of particles obtained from high-density wood species in particleboard production causes a worsening of mechanical properties [Dias et al. 2005]. Therefore, mechanical properties may deteriorate with an increase in growing altitude.

Additionally, an increase in the drying temperature of the particles led to a decrease in the bending resistance values of the boards. High drying temperatures applied to the particles reduce hydroxyl groups [Albrektas and Ukvalbergienė 2015]. Reduced hydroxyl groups cause poor adhesion. The lack of a sufficient bonding surface between the particles may cause the board to have low flexural properties. It was determined that flexural properties improved with increases in press temperature. Similar results were reported by Tabarsa et al. [2010] and Tiryaki et al. [2017].

Lignin is plasticized in the cell structure by the temperature applied to particles [Bouajila et al. 2005]. Because the lignin in the surface layers of the boards was plasticized with an increase of the press temperature, this might have resulted in an increase in bending resistance values. The highest values for MOE were obtained in samples from the Çamoba region. However, the increase in altitude caused the MOE values to decrease in the overall results. The increase in press temperature and particle drying temperature also gave parallel results for the MOR values.

Internal bonding (IB) strength is one of the most important factors in determining the quality characteristics of particleboards. This parameter not only reflects the quality of bonding between the particles and the adhesive used, but also causes changes in other physical and mechanical properties of the boards [Melo et al. 2014]. The IB results showed that the boards met the required level of IB stated in EN 312:2005 for Type P2, P4 and P6 (> 0.40 MPa). Additionally, all of the board types had higher IB than the value stated in the standard for dry and humid conditions.

IB values decreased when the altitude and particle drying temperature increased, while press temperature generally did not affect the IB values. This was because the volume of wood elements decreased and the number of wood elements per unit area increased. More wood elements per unit area might result in a higher number of glued particles and increase the IB resistance by providing better adhesion. Moreover, it was observed that an increase in board density led to an increase in the IB values.

Kakaras and Papadapoulos [2004] found that increasing particle drying temperature caused a reduction in IB, and for this reason the particles, which lost their hygroscopic properties, could absorb less adhesive and reduce the adhesion resistance, which may result in poor adhesion in the core layer. On the other hand, a previous study [Cuk et al. 2011] reported that increasing the press temperature led to an increase in the IB of the boards, because enough hardening of the adhesive occurred due to the greater heat transfer to the core layer with increasing press temperature.

The SW results showed that all of the boards met the minimum required level of SW stated in EN 312:2005 for Type P2 (> 650 N). Generally, the increase in press temperature and high altitude had the effect of reducing SW values. However, increased particle drying temperature positively affected SW values.

Conclusions

This study was carried out to determine the effects of tree growing altitude, particle drying temperature and press temperature on some physical and mechanical properties of particleboards produced from black alder woods. The results indicated that:

1. Particle drying temperature did not affect the density of the boards.
2. The density of the board decreased with an increase in altitude because alder wood had thinner vessel diameter at the higher altitude.
3. The density of the boards increased with an increase in press temperature.
4. With an increase in growing altitude, the WA values of all board groups decreased.
5. An increase in particle drying temperature and press temperature led to a decrease in the WA and TS values of the boards, because of changes in the structure of the wood cell components.
6. The lower altitude improved the mechanical properties of the board, because the volume of wood elements was reduced and the number of wood elements per unit area increased.
7. Mechanical properties of the boards decreased with an increase in the particle drying temperature, because reduced hydroxyl groups caused poor adhesion.
8. Mechanical properties increased with an increase in press temperature, because lignin was plasticized in the cell structure by the high temperature.

References

Abdulkareem S.A., Raji S.A., Adeniyi A.G. [2017]: Development of particleboard from waste styrofoam and sawdust. Nigerian Journal of Technological Development 14 [1]: 18-22. DOI:10.4314/njtd.v14i1.3

Albrektas D., Ukvalbergienė K. [2015]: Impact of wood species, dimensions and drying temperature on sorption behaviour of wood. Wood Industry/Drvna Industrija 66 [1]: 3--10. DOI:10.5552/drind.2015.1369

Baas P., Esser P.M., Van der Westen M.E.T., Zandee M. [1988]: Wood anatomy of Oleaceae. IAWA Bulletin 9: 103-182

Bakhshi R. [2003]: The influence of altitude on wood properties of cypress wood in western part of Mazandran province-Iran, Ph.D. Thesis, Islamic Azad University of Science and Research Branch. Iran

Bouajila J., Limare A., Joly C., Dole, P. [2005]: Lignin plasticization to improve binderless fiberboard mechanical properties. Polymer Engineering and Science 45 [6]: 809-816. DOI: 10.1002/pen.20342

Cuk N., Kunaver M., Medved S. [2011]: Propertıes of partıcleboards made by usıng an adhesıve wıth added lıquefıed wood. Materials and Technology 45 [3]: 241-245

Dias F.M., Nascimento M.F.D., Martinez-Espinosa M., Lahr F.A.R., Valarelli I.D.D. [2005]: Relation between the compaction rate and physical and mechanical properties of particleboards. Materials Research 8 [3]: 329-333

Dönmez I.E., Hafızoğlu H., Kılıç A. [2013]: Effect of altitude on the main chemical composition of Scots pine (*Pinus sylvestris* L.). Proceedings of: International Caucasian Forestry Symposium, 24-26 October 2013. Artvin: 866-869

Esteves B.M., Pereira H.M. [2009]: Wood modification by heat treatment: A review. BioResources 4 [1]: 370-404

Henriques A., Coelho, C., Ferra J., Martins J.M., Magalhaes F.D., Carvalho L. [2017]: Introduction of advanced functionalities in laminates for wood based panels: surface quality evaluation. In Aguilera, A., Davim, J.P. (eds.). Wood Composites: Materials, Manufacturing and Engineering. Walter de Gruyter GmbH & Co KG

Ives E. [2001]: A Guide to Wood Microtomy. Sproughton, Nijhoff / Junk Publishers

Kahveci E. [2012]: Effects to some physical and mechanical features of black alder (*Alnus glutinosa* subsp. *barbata* (C.A. Mey.) Yalt.) wood of different site conditions. Master Thesis, Karadeniz Technical University, Trabzon, Turkey

Kakaras I.A., Papadopoulos A.N. [2004]: The effects of drying temperature of wood chips upon the internal bond strength of particleboard. Journal of the Institute of Wood Science 16 [5]: 277-279

Kartal S.N., Hwang W.J., Imamura, Y. [2008]: Combined effect of boron compounds and heat treatments on wood properties: Chemical and strength properties of wood. Journal of Materials Processing Technology 198 [1-3]: 234-240. DOI: 10.1016/j.jmatprotec. 2007.07.001

Kaygin B., Esnaf S., Aydemir D. [2017]: The effect of altitude difference on physical and mechanical properties of Scots pine wood grown in Turkey-Sinop province. Wood Industry/Drvna Industrija 67 [4]: 393-397. DOI:10.5552/drind.2016.1524

Kiaei M. [2012]: Effect of site and elevation on wood density and shrinkage and their relationships in *Carpinus betulus*. Forestry Studies in China 14 [3]: 229-234. DOI: 10.1007/s11632-012-0310-3

Kiaei M., Kord B., Chehalmardian A., Moya R., Farsi M. [2015]: Mineral content in relation to radial position, altitude, chemical properties and density of Persian ironwood.

Ma Maderas: Ciencia y Tecnologia 17 [3]: 657-672. DOI: 10.4067/S0718-221X2015 005000058

Kiaei M., Samariha A. [2011]: Relationship between altitude index and wood properties of *Pinus eldarica* medw (case study in north of Iran). Gazi University Journal of Science 24 [4]: 911-918

Kord B., Zare H., Hosseinzadeh A. [2016]: Evaluation of the mechanical and physical properties of particleboard manufactured from Canola (*Brassica napus*) straws. Maderas: Ciencia y Tecnologia 18 [1]: 09-18. DOI: 10.4067/S0718-221X2016005000002

Korkut S., Cabukoglu F., Ozdemir H. [2015]: Effects of post heat-treatment on certain characteristics of high density fiberboard. Düzce University Journal of Forestry 11 [1]: 1--15

Li N., Chen Y., Yu H., Xiong F., Yu W., Bao M., Wu Z., Huang C., Rao F., Li J., Bao Y. [2017]: Evaluation of optical properties and chemical structure changes in enzymatic hydrolysis lignin during heat treatment. RSC Advances 7 [34]: 20760-20765. DOI: 10.1039/c7ra02005h

Masraf Y. [2005]: The effects of the physically and mechanically specialities in boards when the production's conditions change, on the production of the particle board that three layer with lying particle. Master Thesis. Zonguldak Karaelmas University. Zonguldak, Turkey

Melo R.R.D., Stangerlin D.M., Santana R.R.C., Pedrosa T.D. [2014]: Physical and mechanical properties of particleboard manufactured from wood, bamboo and rice husk. Materials Research 17 [3]: 682-686. DOI:10.1590/S1516-14392014005000052

Merev N. [1998]: Wood Anatomy Volume I: Wood Anatomy of Natural Angiosperma Taxons in Eastern Black Sea Region. Trabzon: Karadeniz Technical University Press

Milch J., Vavrcik H., Tippner J., Brabec M. [2016]: The effect of growth conditions in specific areas of Croatia and the Czech Republic on the physical and mechanical properties of black alder wood (*Alnus glutinosa* Gaertn.). Turkish Journal of Agriculture and Forestry 40 [1]: 7-12. DOI: 10.3906/tar-1407-40

Nemli G. [1995]: The effect of coating with melamine impregnated papers on the technical properties of particleboard. Master thesis. Karadeniz Technical University. Trabzon, Turkey

Nemli G. [2002]: Factors affecting the production of e1 type particleboard. Turkish Journal of Agriculture and Forestry 26: 31-36

Noack D., Schwab E., Bartz A. [1973]: Characteristics for a judgment of the sorption and swelling behavior of wood. Wood Science and Technology 7 [3]: 218-236

Patera A., Derome D., Griffa M., Carmeliet J. [2013]: Hysteresis in swelling and in sorption of wood tissue. Journal of Structural Biology 182 [3]: 226-234. DOI: 10.1016/j.jsb.2013.03.003

Raskila S., Saranpää P., Fagerstedt K., Laakso T. [2006]: Growth rate and wood properties of Norway spruce cutting clones on different sites. Silva Fennica 40 [2]: 47-255

Sarı B., Nemli N., Ayrilmis N., Baharoğlu M., Bardak S. [2013]: The influences of drying temperature of wood particles on the quality properties of particleboard composite. Drying Technology 31 [1]: 17-23.

Sarıbaş M., Yaman Ö. [2009]: Xylological Study On Hackberry (Celtis Australis L.) Growing Naturally in Antalya- Kemer And Zonguldak Devrek. Journal of Bartin Faculty of Forestry 11 [5]: 1-15.

Tabarsa T., Ashori A., Gholamzadeh M. [2010]: Evaluation of surface roughness and mechanical properties of particleboard panels made from bagass. Composites Part B: Engineering 42 [5]: 1330-1335. DOI: 10.1016/j.compositesb.2010.12.018Get

Tiryaki S., Aras U., Kalay Cıoğlu H., Erişir E., Aydın A. [2017]: Predictive models for modulus of rupture and modulus of elasticity of particleboard manufactured in different pressing conditions. High Temperature Materials and Processes 36 [6]: 623-634. DOI: 10.1515/htmp-2015-0203

Topaloglu E., Ay N., Altun L., Serdar B. [2016]: Effect of altitude and aspect on various wood properties of Oriental beech (*Fagus orientalis* Lipsky) wood. Turkish Journal of Agriculture and Forestry 40 [3]: 397-406. DOI: 10.3906/tar-1508-95

Usta A., Yilmaz M., Kahveci E., Yilmaz S., Öztürk H. [2014]: Effects of different site conditions on some of the wood properties of black alder (*Alnus glutinosa* (L.) gaertner subsp. *barbata* (C.A. Meyer) Yalt). Fresenius Environmental Bulletin 23 [8]: 1840-1851

Wodzicki T.J. [2001]: Natural factors affecting wood structure. Wood Science and Technology 35: 5-26

List of standards

ASTM D1037:2006 Standard methods of evaluating the properties of wood-based fiber and particle panel materials

EN 310:1993 Wood based panels, determination of modulus of elasticity in bending and bending strength

EN 312:2005 Particleboards – specifications

EN 317:1993 Particleboards and fiberboards, determination of swelling in thickness after immersion

EN 319:1993 Particleboards and fiberboards, determination of tensile strength perpendicular to plane of the board

EN 320:1993 Fiberboards. Determination of Resistance to Axial Withdrawal of Screws

EN 323:1993 Wood-based panels. Determination of density

Acknowledgements

The authors thank Kastamonu Integrated Wood Company in Balikesir, Turkey for help in carrying out the production and performance test.

Submission date: 8.07.2019

Online publication date: 14.05.2021