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EFFECT OF BOARD DENSITY, RESIN PERCENTAGE AND PRESSING TEMPRATURE ON PARTICLEBOARD PROPERTIES MADE FROM MIXING OF POPLAR WOOD SLAB, CITRUS BRANCHES AND TWIGS OF BEECH

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ABSTRACT

In this study, construction conditions of homogenous particleboard manufactured from mixing of poplar wood (*Populus alba*) slab, citrus branches and beech (*Fagus orientalis*) twigs have been investigated. The density of particleboard at three levels of 0.65, 0.7 and 0.75 g·cm^{-3}, the amounts of resin at two levels of 9 and 11% and the amounts of pressing temperature at two levels of 160 and 170° C were considered. Increasing the density from 0.65 to 0.75 led to an increase in MOR, MOE and IB. By increasing the density, water absorption of particleboard decreased but its thickness swelling increased. By increasing the resin percentage the mechanical properties of particleboard improved, although this improvement was not statistically significant. Furthermore, by increasing the resin percentage the dimensional stability of particleboard improved partially. Not only did increasing the pressing temperature have any significant effect on the improving of mechanical properties of the particleboard, but also it has even led to a decrease in IB. Increasing the pressing temperature reduced the water absorption of particleboard in the short term (2 hours) while this increase led to a further increase in the thickness swelling of particleboard.

KEYWORDS: Particleboard, density, urea-formaldehyde resin, pressing temperature.

INTRODUCTION

Through dramatic increase in population and then expansion of construction particularly in major cities, demands for consuming lignocellulosic products especially particleboard increased (Nourbakhsh and Kargarfard 2006). Among the wood composite industries, particleboard industry has developed dramatically due to use of low-value timbers, wood wastes and lignocellulosic wastes to produce a product with diverse and desired functional properties (Enayati et al. 2014). In Iran, due to lack of forest resources, most of the factories of wood and paper industries have to use their supplement of raw materials from wood wastes, agricultural residues, branches of fruit trees and non-fruit bearing trees and other lignocellulosic resources. As we know, various factors affect the particleboard properties such as type of species, type and amount of resin, the percentage of wood particles moisture, pressing time and temperature, board density, etc. (Doosthoseini 2008). Board density is one of the most important factors that affects the properties of particleboard and other wood composites, to the extent that by increasing this factor, many of functional properties of boards are improved (Eslah et al. 2012).

The type and amount of resin used can also affect the quality of wood composites including particleboard. The quality of particleboard is increased by increasing the amount of resin due to better distribution of resin on the wood particles and increasing the connection points between wood and resin (Dahmardeh Ghalehno et al. 2013).

Pressing temperature also affects the quality of produced particleboard so much that by increasing the adhesive bonding rate due to increase pressing temperature, the functional properties of particleboard are improved (Malanit et al. 2009). The type of species and the way to mix the lignocellulosic materials for the production of particleboard can also affect the quality of products. The characteristics of species such as density, moisture percentage, chemical compound and other properties can have effect on various factors of production (Doosthoseini 2008). In manufacturing wood composites, based on the composition of the products, it is better to look for the most optimal modes of production factors such as board density, amount of resin, pressing temperature and time, etc. As was previously said, in Iran due to shortage of forest resources, most of the factories of wood and paper industries have to use their supplement of raw materials from wood and non-wood wastes. Therefore, in order to enhance the quality of products, studies should be done on the factors which affect production.

In this research, we tried to study the effect of density of board, the amount of resin and pressing temperature on the quality of manufactured particleboard from mixing of poplar wood slab, citrus branches and twigs of beech. About the effect of listed parameters in this study on the particleboard quality, some research have been done that some of them are mentioned in this article.

Noorbaksh and Kargarfard (2006), in a research about the effect of density on poplar insulation particleboard properties, concluded that by increasing the density, the MOE, MOR and IB increased while the TS decreased.

Lias et al. (2014) in the investigation of influence of board density on the homogenous particleboard properties from kelempayan (*Neolamarckia cadamba*) concluded that increasing the density led to an improvement in most of the properties in particleboard.

Jazayeri et al. (2007) studied the effect of resin content and pressing temperature on the properties of particle board from Acacia salicina wood. They concluded that by increasing the amount of resin from 9% to 11%, the MOR and IB of particleboard significantly increased while the TS significantly decreased. They also concluded that the increase in the pressing temperature from 165 to 175°C, among the properties of particleboard, just had a significant effect on the MOE of particleboard, so it is reduced.

Tabarsa (2011), in study of producing particleboard using mixture of bagasse and industrial wood particles concluded that increasing the pressing temperature from 165 to 180°C led to an improvement in most of the properties of particleboard.

MATERIALS AND METHODS

Materials preparation

Wood particles were prepared from Pars Particleboard Complex in Nashtarood, Tonekabon that is located in north of Iran. The particles consist of poplar wood slab, garden resources (citrus branches) and twigs of beech. The particles were dried down to 3% moisture content by a circular dryer and were classified to eliminate over- and undersized by screening machines and were packaged in a strong humidity proof plastic bags to make boards. Urea-formaldehyde (UF) resin was supplied by Iran-Choob Qazvin Co. The properties of UF resin are presented in Tab. 1. In this study, hardener of ammonium chloride as a liquid form was used.

Tab. 1: Resin specification.

Properties	Content
Solid content (%)	63
Viscosity (CP)	370
Density ($g \cdot cm^{-3}$)	1.286
Free formaldehyde (%)	0.5
pH	7.5
Gel time (Second)	59

Particles dimensions

The following (Neusser and Krames 1969) instructions, 2 g wood particles were randomly chosen among particles with suitable dimension and their length, width, thickness, slenderness ratio and aspect ratio of 30 of them were estimated by micrometer, shown in Tab. 2.

Tab. 2: Average of dimension, slenderness ratio and aspect ratio of wood particles.

Dimension (mm)			Slenderness ratio (L/T)	Aspect ratio (L/W)
Length	Width	Thickness	23.12 (7.31)	5.9 (1.62)
14.8 (4.6)	2.51 (0.8)	0.64 (0.23)		

Note: The numbers in parentheses are standard deviations.

Making particleboard

The particles were blended with UF resin in a rotating drum-type mixer, fitted with a pneumatic spray gun. The materials were placed in a mat forming box manually formed. Mat forming box with dimension of 40 x 40 x 25 cm used and the glued particles spread over into a frame in shape of monotonous layers that were weighted by screening lab. Variable factors in this study consist of 9 and 11% resin contents based on particles dry weight, and board density that are at three levels 0.65, 0.70 and 0.75 $g \cdot cm^{-3}$ and hot pressing temperature in 160 and 170°C were applied. Three replicate boards were fabricated for each treatment. Over all thirty six experimental boards were made. Other factors in this study consisted of pressing time in 6 minutes, pressing pressure 30 $kg \cdot cm^{-2}$, amount of hardener use in level of 1% (based on dry weight of used resin) and also thickness of boards that were 16 mm. They were fixed for all the boards. After forming mat, the materials were placed in a mat forming box manually formed. The mats were pressed by BURKLE L160. The panels were conditioned at a temperature of

20±2°C and 65±5% in relative moisture content for about 15days and then cut into test specimens according to EN 326-1 standard. The number of samples for each treatment was 3. Tab. 3 presents experimental samples.

Tab. 3: Experimental samples dimension.

Properties	Length (mm)	Width (mm)	Thickness (mm)
MOR & MOE	370	50	16
IB	50	50	16
TS & WA	50	50	16

Physical and mechanical testing

Physical properties which consist of thickness swelling (TS) and water absorption (WA) were evaluated based on EN-317 in two periods of time 2 and 24 hours. Mechanical properties which consists of rupture (MOR) and module of elasticity (MOE) were determined in accordance with EN-310 by Instron machine 4486 and internal bonding (IB) was determined in accordance with EN-319 by WOlPERTD 6.6700 machine. In order to calculate and determine the humidity and specific gravity of boards, they were used by EN-323 and EN-322, respectively.

Statistical method

The results were examined through three variables and fully randomized process in which factorial experiments, Duncan test (DMRT) and variance analysis technique were employed. Through these statistical methods, the mutual and independent effect of each variable factor on the physical and mechanicalproperties of particleboard was analyzed at the trust levels of 99% and 95%.

RESULTS AND DISCUSSION

The physical and mechanical properties of the particleboard

Mechanical and physical properties of particleboard production according to the target density, the pressing temperature and percentage of resin were measured and the average results of these measurements are in the Tab. 4.

Tab. 4: Physical and mechanical properties of the produced particleboard.

Density ($g \cdot cm^{-3}$)	Pressing temp. (°C)	Resin content (%)	MOR (MPa)	MOE (MPa)	IB (MPa)	WA 2h (%)	WA 24h (%)	TS 2h (%)	TS 24h (%)
0.65	160	9	9.48	1003.2	0.24	44.85	69.09	13.09	21.46
	170	11	9.48	1208.3	0.26	44.03	62.61	15.27	20.04
	160	11	8.49	1155	0.22	43.22	61.55	9.96	15.42
	170	9	9.39	1132.7	0.23	46.79	71.22	16.71	20.22
0.7	160	9	10.66	1282.3	0.22	48.98	64.63	16.67	22.34
	170	11	9.22	1114.7	0.21	36.83	64.43	14.15	17.28
	160	11	10.67	1332.3	0.25	48.92	60.58	13.02	19.30
	170	9	9.91	1238.3	0.23	42.26	65.92	16.30	20.19

0.75	160	9	11.09	1255.7	0.25	48.42	70.27	17.54	22.04
	170	11	11.35	1526.7	0.21	37.26	66.66	17.10	27.03
	160	11	12.05	1459	0.28	46.84	65.06	13.60	18.84
	170	9	12.36	1517.3	0.24	38.45	67.13	16.85	22.1

Based on the table, the maximum value of MOR is related to the density of 0.75 $g \cdot cm^{-3}$, pressing temperature of 170°C and resin content of 9% and the maximum value of MOE are related to the density of 0.75 $g \cdot cm^{-3}$, pressing temperature of 170°C and resin content of 11% and the maximum value of IB are related to the density of 0.75 $g \cdot cm^{-3}$, pressing temperature of 160°C and resin content of 11%.Thus, it can be comprehended that in the entire made up boards, the highest MOR, MOE and IB values are respectively 12.36, 1526.7 and 0.28 MPa which are related to the density of 0.75 $g \cdot cm^{-3}$.

As for the physical features, the maximum value of WA after 2 hours immersion in water is related to the density of 0.7 $g \cdot cm^{-3}$, pressing temperature of 160°C and resin content of 9%, the maximum of WA after 24 hours immersion in water are related to the density of 0.65 $g \cdot cm^{-3}$, pressing temperature of 170°C and resin content of 9%, the maximum of TS after 2 hours immersion in water are related to the density of 0.75 $g \cdot cm^{-3}$, pressing temperature of 160°C and resin content of 9% and the maximum of TS after 24 hours immersion in water are related to the density of 0.75 $g \cdot cm^{-3}$, pressing temperature of 170°C and resin content of 11%. So it seems that with such increased density, the WA reduces but the TS of samples increases.

Statistical analysis

The results of variance analysis of MOR, MOE, IB, WA and TS after 2 and 24 hours immersion in water of particleboard have been shown in Tab. 5.

Tab. 5: Variance analysis of mechanical and physical properties of particleboard.

Source	MOR	MOE	IB	WA(2h)	WA(24h)	TS(2h)	TS(24)
Pressing temperature	ns	ns	ns	**	ns	**	ns
Resin percentage	ns	ns	ns	ns	**	**	ns
Density	**	**	ns	ns	*	**	*
Temperature × Resin	ns	ns	ns	ns	ns	*	*
Temperature × Density	ns	ns	ns	*	ns	*	ns
Resin × Density	ns	ns	ns	ns	ns	ns	ns
Temperature × Resin × Density	ns	ns	ns	ns	ns	ns	ns

Note: ns (not significant), * (significant on α=5%), ** (significant on α=1%)

As it is shown in the Tab. 5 of variance analysis, the pressing temperature and the percentage of resin have no significant effect on the mechanical properties of the particleboard at all. However, the independent effect of density on the MOR and MOE of the particleboard is significant and its effect on the IB is not significant. Testing the interaction effect of each factors above on the mechanical properties of the particleboard shows the effect of pressing temperature, the percentage of resin, the effect of the pressing temperature and density, the effect of the resin percentage and density, the effect of the pressing temperature, resin percentage and density that did not have any significant effect on the mechanical properties of the particleboard.

The independent effect of pressing temperature on WA and TS after 2 hours immersion in water is significant but insignificant in 24 hours. The independent effect of resin percentage on

WA after 24 hours and TS after 2 hours is significant but the WA after 2 hours and TS after 24 hours is not. The independent effect of density on WA after 24 hours and TS after 2 and 24 hours is significant, but the WA after 2 hours is not.

The dependent effect of pressing temperature and resin percentage on WA after 2 and 24 hours is insignificant, but these two items on TS after 2 and 24 hours is significant. The dependent effect of the pressing temperature and the density on TS and WA after 2 hours are significant but on TS and WA after 24 hours is not. The dependent effect of density and resin percentage, the dependent effect of the pressing temperature, density and resin percentage on any features of the board are insignificant.

The effect of density on the physical and mechanical properties

One of the most important factors affecting the properties of particleboard and other wood composite products is board density. Fig. 1 shows the effect of board density on the mechanical properties. In this figure by increasing the density, strength characteristics that include MOR, MOE and IB also improve. However in MOR and MOE, with the change of density from 0.65 to 0.7 g·cm^{-3} the effect of it is insignificant but it is significant in density of 0.75 g·cm^{-3}.

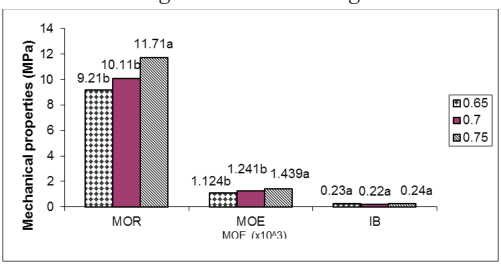

Fig. 1: The effect of density on the mechanical properties.

According to the results of IB we came up with the small amount of reduction in the density of 0.7 to 0.65 g·cm^{-3} which is neither significant nor increased but there is the highest value of IB in the density of 0.75 g·cm^{-3} that is also insignificant.

By increasing the density of the board the mechanical strength increased which is confirmed by Eslah et al. (2012) and Lias et al. (2014) who also reported the same process. The reason of such increase is that when the board density increases, it causes an increase in compression rate and contact between wood particles and results in improvement of the mechanical properties. As a result such improvement in connection may strengthen the resistance features of the board. In fact, several studies show that there is a high correlation between density and features of the board (Eslah et al. 2012). Figs. 2a and 2b show the effect of density on the physical properties of particleboard.

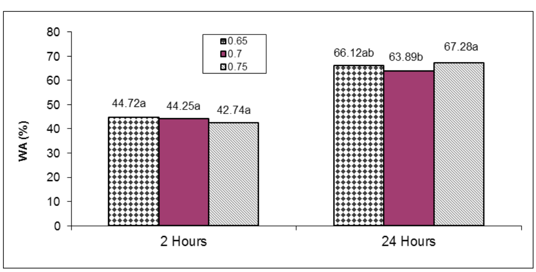

Fig. 2a: The effect of density on the WA after 2 and 24 hours.

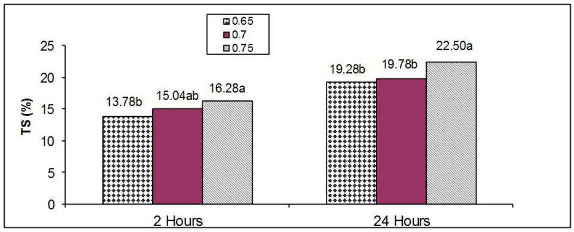

Fig. 2b: The effect of density on the TS after 2 and 24 hours.

By increasing the density, WA decreases after 2 hours but statistically the results are insignificant. WA decreases after 24 hours with the density of 0.7 g·cm^{-3} in comparison with the density of 0.65 g·cm^{-3}, but increases right away in the density of 0.75 g·cm^{-3}, which of course is insignificant. Not to mention there is no difference between 0.75 and 0.65 g·cm^{-3} in this case. With such increase in density, TS increases after 2 and 24 hours to the extent that in both 2 and 24 hours TS occurred in the density of 0.75 g·cm^{-3} in comparison with the densities of 0.65 and 0.7 g·cm^{-3} which is significant. Overall such increase in density causes WA reduction and TS increase in the short run. It is concluded that by increasing the density, the WA reduces and the TS increases which is also reported by Lias et al. (2014). By increasing the density of the board due to compacting and reduction of the pores between particles, the ways of entering and absorbing the water reduces in the particleboard (Doosthoseini, 2008). As it is occurred in WA after 2 hours, it is clear with increasing density the WA decreases. Furthermore with the lower density, the lower TS appeared in comparison with the other higher densities.

The reason for such process can be explained as decreasing the board density will lead to reduction of the amount of wood material per unit volume. In such extent there is slight TS which is transferred and spread over into the space between the particles of the board (Doosthoseini 2008).

Therefore by increasing the board density due to having more wood material, the dimensional stability of the board decreases (Lin et al. 2008). Such conclusion is also reported by Lias et al. (2014), Eslah et al. (2012), Lin et al. (2008) Kalaycioglu et al. (2005) have reported.

Effect of resin percentage on the mechanical and physical properties

The percentage of resin used in manufacturing the wood panels such as particleboard is effective on improving mechanical and physical properties of the board. Therefore, resin makes a strong connection between particles inside the board (Kong Wong 2012). Several studies have shown that by increasing the amount of resin, physical and mechanical properties of particleboard improve. Fig. 3 shows the independent effect of resin on mechanical properties of the particleboard. Although the statistical analysis shows insignificant difference in mechanical properties between the 9 and 11 percent of resin, by increasing the amount of resin from 9 to 11 percent, all the mechanical properties of the particleboard improve.

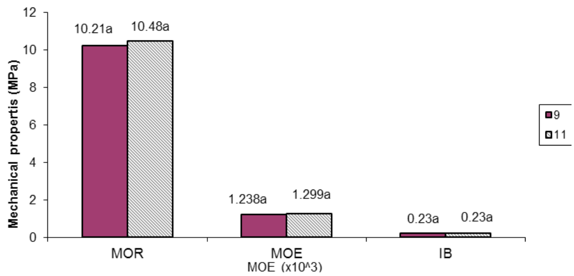

Fig. 3: The effect of resin content on the mechanical properties.

By increasing the amount of resin, there is a complete resin coating on the whole particles, therefore by making more bonding sites between the particle and resin the mechanical properties such as the MOR, MOE and IB increase (Dahmordeh et al. (2013). Zheng et al (2006), Lin et al. (2008), Guntekin and Karakus (2008), Papadopoulos et al. (2002), Nemli and Kalacioglu (2001), Gamage et al. (2009) and Dahmordeh Ghalehno et al. (2013) also have reported that by increasing the amount of resin the mechanical features of board improve.

Figs. 4a and 4b, show the independent effect of resin percentage on the physical properties of the made up particleboard.

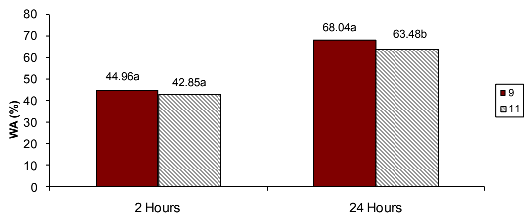

Fig. 4a: The effect of resin content on the WA after 2 and 24 hours.

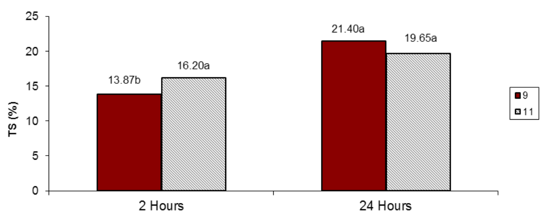

Fig. 4b: The effect of resin content on the TS after 2 and 24 hours.

By increasing the amount of resin from 9 to 11%, the WA and TS of particleboard after 2 and 24 hours immersion in water decrease. Statistically this reduction in the WA after 2 hours and the TS after 24 hours is insignificant, but the WA after 24 hours and the TS after 2 hours is significant. In the production process of the wood panels, the most important aim of blending is to create a thin layer of resin on the surface of particles. The properties of the made up board especially physical properties of the board improve, if it is possible, there may be a steady and complete amount of resin all over the particles (Doosthoseini 2008).

Regarding this fact in making particleboard, wood particles have high specific surface and surface roughness more and also that a considerable amount of resin in the pores and voids between the particles are out of reach very much. Apart from technical issues, it seems that by increasing the amount of resin, it might be possible to have somewhat more complete resin coating on the wood particles. By increasing the connections between wood particles and resin, it approximately can prevent entering the water molecules in the space between particles. As a result it enhances the stability of boards made in this study. Zheng et al. (2006), Lin et al. (2008), Guntekin and Karakus (2008), Papadopoulos et al. (2002), Nemli and Kalacioglu (2001), Gamage et al. (2009) and Dahmordeh et al. (2013) have reported that by increasing the resin, the stability of particleboard improves.

Effect of pressing temperature on the mechanical and physical properties

The role of pressing temperature in the pressing of particleboard mat is very important and noticeable. Pressing temperature and time are important factors which affect the quality of production boards (Iswanto et al. 2013). Adjusting the temperature and time of pressing could be conducted through two mechanisms: increasing pressing time at a constant temperature and increasing temperature at a constant pressing time (Wang and Dai 2003). In this study by making the pressing time as stable, the effect of increasing pressing time on the properties of the particleboard was studied. Fig. 5 shows the effect of pressing temperature on the mechanical properties of produced particleboard.

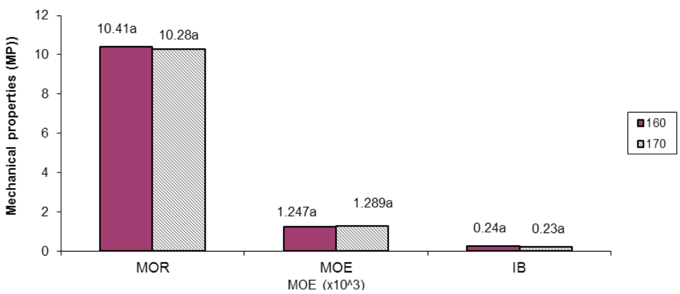

Fig. 5: The effect of pressing temperature on the mechanical properties of produced boards.

There is an increase in pressing temperature which had insignificant effect on any of the mechanical properties. In each of the temperatures the MOR is almost identical. At a temperature of 170°C, there is a slight increase in MOE. In fact, even at this temperature (170°C), there is a descent of IB in comparison with the temperature of 160°C. A higher Pressing temperature increases the adhesive bonding rate, which will enhance the strength. A lower temperature during the hot pressing process results in the low strength because the resin does not cure. In addition, when the very high temperature is used, the resin will be over cured. Both of these conditions will reduce the bonding strength in adhesive bond (Malanit et al. 2009). Therefore, we must be looking for an optimum temperature in manufacturing process. It seems the pressing temperature of 170°C has failed to have a large positive effect on the mechanical properties of the particleboard so that there is only a slight increase in the MOE which is also reported by Iswanto et al. (2013) and Gupta et al. (2011). Thus it should be noted beside the effect of the pressing temperature on MOE, there are other factors such as type and content of the resin, adhesive bonding strength and the fiber length which also affect the MOE (Maloney 1993).

Insignificant differences of the temperature on MOR between 160 and 170°C also suggest that by increasing the temperature in this research, the MOR may not improve. Iswanto et al. (2013) examined the effect of pressing time and pressing temperature on MOR of the board. They also reported that the pressing time had a significant effect on the MOR, but the pressing temperature had insignificant effect on it. It should be noted that in other studies, the increase in pressing temperature causes a significant increase in the MOR, including the report of Gupta et al. (2011), Dahmarde et al. (2011), Nemli and Kalaycioglu (2001), Kalaycioglu and Nemli (2006), Guler and Ozen (2004). There is a reason why the increase in the temperature in this study did not lead to the increase in MOR. According to the structure and the condition of the particleboard (type, content and geometry figures of wood and lignocellulosic material particles, type and content of resin, pressing time and etc.), perhaps the highest temperature (170°C) is a critical temperature which makes the adhesion turns back.

Considering the effect of the pressing temperature on IB, it is expected that the increase in temperature improved IB but it is observed that in 170°C the IB of the particleboard might decrease a little. In the other researches it is also reported that increase in pressing temperature was the reason of improvement in IB (Gupta et al. 2011, Dahmarde and Nazerian, 2011, Nemli and Kalaycioglu, 2001, Kalaycioglu and Nemli, 2006, Guler and Ozen 2004). Therefore, higher temperature, instead of helping the adhesion of the resin had a negative effect on IB. However based on the achieved result on this research, the amount of IB between these two temperatures (160 and 170°C) was insignificant.

Figs. 6a and 6b, show the effect of temperature on the physical characteristics of produced particleboard.

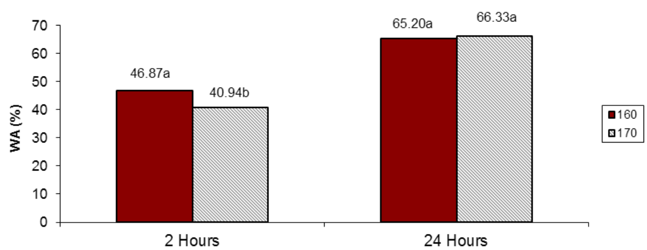

Fig. 6a: The effect of pressing temperature on WA after 2 and 24 hours.

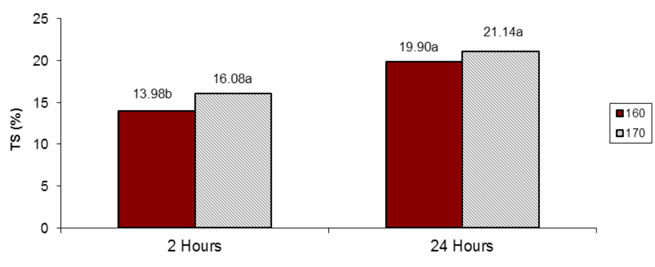

Fig. 6b: The effect of pressing temperature on TS after 2 and 24 hours.

As it is shown, with increase in the pressing temperature the WA after 2 hours in water reduced significantly. The WA after 24 hours did not show significant change. The TS increased after 2 and 24 hours, of course in 2 hours the increase is significant, but insignificant in 24 hours. The increase in pressing temperature at the same time reduced water absorption of the particleboard (Iswanto et al. 2013). In this study, at least in short term (WA after 2 hours), by increasing the pressing temperature, there is a reduction in WA which Iswanto et al. (2013) also have reported such an occurrence. In their research there is the lowest WA between pressing temperature of 110, 120 and 130°C which is related to temperature of 120°C. In addition, Dahmardeh et al. (2010) in their study concluded that the increase in temperature reduces the WA of the board. Despite the expectation of the increase in pressing temperature, it reduces TS but there is an opposite reaction that happens at the temperatures of 170°C that increases TS. Such increase in TS is modest but not statistically significant even in 24 hours. According to its terms, the pressing temperature of 170°C is not appropriate and in some cases had an inverse effect on the features.

CONCLUSIONS

In this study, the effect of board density, resin content and pressing temperature on the mechanical and physical properties of particleboard were investigated. Particleboard was produced from mixing of poplar wood slab, citrus branches and twigs of beech. The results showed that by increasing the density, mechanical properties also increased. Due to increasing the density and higher compaction, the connection points between wood and resin increased that would lead to improving mechanical properties.

By increasing the density of the particleboard, WA reduced and TS increased. It seems that with increasing the board density regarding more compaction of particles and reduction of pores between them, the amount of WA would decrease. However by having a higher density due to the increasing of the amounts of particles in per unit volume, the amount of TS would increase.

By increasing the resin content the mechanical properties of particleboard improved. There is a reason that by increasing the percentage of resin, all mechanical properties that improved attributed to the increase of connection points between resin and particles, although the difference of resistances of particleboard between the resins contents of 9 and 11% was not significant. In addition, with increasing the resin percentage and more coating of particles of resin the physical properties of particleboard (WA and TS) improved.

The effect of the increase in pressing temperature on the properties of the particleboard was not considerable. It only created a slight improvement in the WA and MOE and had no significant effect on MOR of the particleboard and even had a negative effect on IB and TS. In other words, it seems that pressing temperature of 170°C which used in this study was somewhat higher temperature and it had a negative effect on the adhesion process.

According to what was mentioned, it seems that in this study the best option among treatments is the particleboard which is produced with the density of 0.75 $g \cdot cm^{-3}$ resin content of 9% and pressing temperature of 160°C.

Considering the standard of EN312, the minimum requirements for MOR of panels for general uses and interior fitments (including furniture application) are 12.5 and 14 MPa, respectively. The minimum requirement for MOE of panels for general uses and interior fitments is 1800 MPa and the minimum requirements for IB of panels for general uses and interior fitments are 0.28 and 0.4 MPa, respectively. Furthermore, the maximum values allowed for the TS of panels after 2 and 24 hours of immersion are 8% and 15%, respectively. Thus, comparing the results of this research with standard values, it became clear that produced panels in this work do not comply with the standard conditions. This research suggests if we want to produce particleboard with the same materials, the production factors should be amended to produce standard panels.

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