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Determination of some properties of particleboards produced with two different adhesives

Mehmet Cülfük[1,*], Kadir Karakuş[1], İlkay Atar[1], İbrahim Halil Başboğa[1], Fatma Bozkurt[1], Fatih Mengeloğlu[1]

[1] Kahramanmaraş Sütçü İmam University,Forest product Engineering, Graduate School of Natural and Applied Sciences, Kahramanmaraş, Turkey
[*] Corresponding author: mehmetculfuk@hotmail.com

Abstract: In this study, particleboards were produced with two different adhesive and two different lignocellulosic materials. Urea formaldehyde and PMDI were used as adhesive. Wheat straw and mixture of pine and poplar particles were utilized as lignocellulosic material. The aim of the study was to determine the effects of type and amount of adhesive, type of lignocellulosic materials on the particleboards properties. In addition, effects of usage layers of the lignocellulosic materials were investigated. For this purpose, sixteen particleboards with single or three layers were produced. Test samples were prepared and their mechanical and physical properties including bending strength, modulus of elasticity in bending, tensile strength perpendicular to the plane of the board, swelling in thickness, water absorption and density of the samples were determined according to EN 310, EN 319, EN 317 and EN 323/1 standards, respectively. As results of this study, the particleboards produced with PMDI adhesive were provided better bending strength, modulus of elasticity, internal bond strength than urea formaldehyde adhesive. Mechanical strength values were increased with rising of adhesive amount. The particleboards produced with urea formaldehyde were absorbed more water and more swelled than PMDI. All the boards manufactured with PMDI adhesive provided standard requirements.
Keywords: Particleboard, Urea formaldehyde, PMDI, Wheat straw, Wood particle

İki farklı tutkal kullanılarak üretilen yonga levhaların bazı özelliklerinin belirlenmesi

Özet: Bu çalışmada iki farklı tutkal ve iki farklı hammadde kullanılarak yonga levhalar üretilmiştir. Hammadde olarak odun yongası ve buğday sapı, tutkal olarak üre formaldehit ve PMDI kullanılmıştır. Çalışmanın amacı üretilen yonga levhaların kalite özellikleri üzerine tutkal türü, tutkal miktarı, hammadde türü ve hammaddelerin yonga levha içerisindeki kullanım yerlerinin etkisinin belirlenmesidir. Bu amaç doğrultusunda tek ve üç tabakalı olmak üzere 16 adet yonga levha üretilmiştir. Üretilen levhaların eğilme direnci, eğilmede elastikiyet modülü değerleri, yüzeye dik çekme direnci, kalınlık artışı, ağırlık artışı (su alma) oranları ve yoğunluk değerleri sırasıyla EN 310, EN 319, EN 317 ve EN 323/1 standartlarına göre belirlenmiştir. Elde edilen istatistik sonuçlarına göre PMDI tutkallı levhalar üre formaldehitli levhalara göre daha yüksek çekme direnci, eğilme direnci, eğilmede elastikiyet modülü değerlerine sahip olduğu görülmüştür. Üretilen levhalarda kullanılan tutkal oranı artıkça mekanik değerlerde artış olduğu belirlenmiştir. Üre formaldehit tutkalı ile üretilen levhalar PMDI tutkalı ile üretilen levhalardan daha çok su alıp şiştiği tespit edilmiştir. PMDI tutkalı ile üretilen yonga levhaların tamamı standartta istenen değerleri sağlamıştır.
Anahtar kelimeler: Yonga levha, Üre formaldehit, PMDI, Buğday sapı, Odun yongası

1. Introduction

The particle board is usually a large surface plate produced under the heat and pressure with the help of glue of small pieces of wood. In the production of particle board, materials such as forest waste, firewood, branch wood, industrial waste wood, timber waste and annual plant stalks are used as wood raw materials. Wood of a type tree can be used as a raw material or woods of different type tree can be used by mixing in the production of particle board. (Akyıldız, 2003; Başyiğit vd, 2000; Bozkurt ve Göker, 1990; Kalaycıoğlu ve Özen, 2012).

Our country is also an important agricultural region, especially because plants such as wheat and cotton are grown in abundant quantities. The stalk of cotton planted in this area is renewable and forms a significant fiber source. Kalaycıoğlu ve Özen (2012) stated that it will be possible to evaluate these wastes as raw materials in the production of chipboard.

Due to its low cost, ease of use and some technical advantages, urea formaldehyde is used in 90% of the production of chipboard industry. Urea formaldehyde can be obtained in both dry and liquid form. (Bozkurt ve Göker, 1990; Kalaycıoğlu ve Özen, 2012). Another adhesive used in the production of chipboard is Polymeric Diphenyl Methane diisocyanate (PMDI). This glue has many advantages such as high resistance to moisture, low pressing time and resistance properties over FF glue, as well as disadvantages such as the sticking of the particle board to the press plates in the first years of use and the price being expensive (Schmidt, 1998).

In a study by Grigoriou (2001), wood chips and wheat stalks were mixed at different rates to produce chipboard. Urea formaldehyde and polymeric diphenyl methane diisocyanate adhesives were used at different rates in the production. As a

result of the tests made, the produced particle boards with PMDI and PM / PMDI adhesives had higher values than the produced particle boards with UF.
The aim of this study was to produce three layered particle board using two different glue and two different raw materials and to determine some properties of them. Tests have been carried out in accordance with the standards. The values obtained are compared with the standard values.

2. Material and method

In this study, wood particle with wheat stalk as raw materials and urea formaldehyde with polymeric diphenyl methane diisocyanate as adhesives were used. Wood particles and urea formaldehyde (UF) were supplied by Kastamonu Integrated industry and trade limited company. Wheat stalks were provided by the local farmers in Kahramanmaraş/Turkey. Polymeric diphenyl methane diisocyanate (PMDI) was supplied microkim chemical and machinery Industry and trade limited company in Turkey. Properties of UF and PMDI were shown Table 1 and Table 2, respectively.

Table 1. Properties of urea formaldehyde

Properties	UF
Solution (%)	65+- 1
Density (g/cm^3)	1.27-1.29
PH (25^{0}C)	7.5-8.5
Viscosity Dın/cPs 25ºC	150-200
Gelling time (s, 100^{0}C)	25-30
Usage time (day)	60
Flow time (s, 25^{0}C)	20-30
Free CH_2O (max.) %	0.19

Table 2. Properties of polymeric diphenyl methane diisocyanate (URL 1)

Physical appearance	Sticky liquid
Color	Brown
Smell	Light Mold
Specific weight	At 200 ^{0}C 1,24
Water Solubility	İnsoluble in water
Boiling Point	300 ^{0}C
Freezing point	5-10 ^{0}C
Reaction	Water, Alcohol, Acids, Bases

The composition of manufactured particle boards is shown in Table 3. Wheat straws and wood particles were first dried in an oven to about 2%. Dried particles and glue were mixed in the mixer machine according to the determined ratios. Glued particles were laid in the mold. First, cold press was applied to the prepared draft board. It was then pressed at 200 ° C at 120 bar pressure for 6 min. 14 groups were successfully produced, but M3 and M7 groups were not produced. The produced particle boards were allowed to cool down in room conditions. The particle boards were cut to standard test sizes. All tests samples were conditioned in a climatic room with the temperature of 20 °C and the relative humidity of 65%. Values of tensile strength perpendicular to the plane of the board, bending strength, modulus of elasticity in bending, swelling in thickness and density were determined according to EN 319, EN 310, EN 317 and EN 323/1, respectively.

Table 3. The composition of manufactured particle boards

Specimen ID	Glue type and ratio (%)		Amount of glue	Particle type and ratio (%)		Amount of particle (gr)		Number of layers and Particle type (WP, WS)
	UF	PMDI	(gr)	WP	WS	WP	WS	
M_1	5	0	139*	100	0	2,685	0	Surface layer WP
M_2	10	0	265*	100	0	2,685	0	Surface layer WP
M_3	5	0	139*	0	100	0	2,264	Surface layer WS
M_4	10	0	265*	0	100	0	2,264	Surface layer WS
								Surface layer WS
M_5	5	0	140*	67	33	1,867	920	Inner layer WP
								Surface layer WS
								Surface layer WS
M_6	10	0	266*	67	33	1,782	878	Inner layer WP
								Surface layer WS
								Surface layer WP
M_7	5	0	140	33	67	878	1,782	Inner layer WS
								Surface layer WP
								Surface layer WP
M_8	10	0	266*	33	67	878	1,782	Inner layer WS
								Surface layer WP
M_9	0	5	139	100	0	2,803	0	Surface layer WP
M_{10}	0	10	265	100	0	2,679	0	Surface layer WP
M_{11}	0	5	139	0	100	0	2,948	Surface layer WS
M_{12}	0	10	265	0	100	0	2,687	Surface layer WS
								Surface layer WS
M_{13}	0	5	140	67	33	1,879	920	Inner layer WP
								Surface layer WS
								Surface layer WS
M_{14}	0	10	315	67	33	1,908	945	Inner layer WP
								Surface layer WS
								Surface layer WP
M_{15}	0	5	140	33	67	948	1,883	Inner layer WS
								Surface layer WP
								Surface layer WP
M_{16}	0	10	315	33	67	965	1,918	Inner layer WS
								Surface layer WP

WP: Wood particle, WS: Wheat stalk

3. Results and discussion

In this study, on the physical and mechanical properties of the chipboard were investigated the effect of glue and raw material type as well as being single or three layered of particle boards. The density values of the particle boards produced using the UF and PMDI glues are given in Table 4 and Table 5. According to test results, it was seen that the lowest density value (0.60gr/cm^3) is the M4 board produced with 10% urea formaldehyde glue and 100% wheat stalks. The highest density value (0.75gr/cm^3) was appeared the M11 board produced using 5% PMDI glue and 100% wheat stalks. It was seen that the density values of the produced particle boards are close to the target density values.

Table 4. The density values of the particle boards produced using the UF

Specimen ID		M1 (gr/cm^3)	M2 (gr/cm^3)	M4 (gr/cm^3)	M5 (gr/cm^3)	M6 (gr/cm^3)	M8 (gr/cm^3)
Glue type	No						
	1	0,71	0,73	0,57	0,73	0,73	0,64
	2	0,70	0,75	0,58	0,73	0,72	0,69
UF	3	0,67	0,74	0,61	0,70	0,73	0,71
	4	0,66	0,74	0,61	0,72	0,74	0,71
	5	0,63	0,74	0,61	0,70	0,73	0,70
Average (%) (X)		0,67	0,74	0,60	0,72	0,73	0,69
Standard deviation (S)		0,03	0,01	0,02	0,02	0,01	0,03

Table 5. The density values of the particle boards produced using the PMDI

Specimen ID		M9	M10	M11	M12	M13	M14	M15	M16
Glue type	No	(gr/cm^3)	(gr/cm^3)	(gr/cm^3)	(gr/cm^3)	(gr/cm^3)	(gr/cm^3)	(gr/cm^3)	(gr/cm^3)
	1	0,62	0,63	0,73	0,71	0,65	0,71	0,70	0,75
	2	0,63	0,71	0,74	0,69	0,67	0,70	0,69	0,73
PMDI	3	0,63	0,70	0,78	0,68	0,66	0,69	0,71	0,73
	4	0,63	0,62	0,76	0,68	0,67	0,67	0,72	0,71
	5	0,62	0,63	0,74	0,70	0,69	0,69	0,70	0,75
Average (%) X		0,63	0,66	0,75	0,69	0,67	0,69	0,70	0,73
Standard deviation (S)		0,00	0,04	0,02	0,01	0,01	0,01	0,01	0,02

The values of swelling in thickness of the samples which are kept in water for 24 hours are given in Table 6 and Table 7.The highest thickness increase value (68,9 %) was appeared the M8 board produced using wheat stalk in the middle layer and 10% UF glue. It was seen that the lowest thickness increase value (8,4 %) is the M10 and M14 board produced with wood particle in the middle layer and 10% PMDI glue .

Table 6. The values of swelling in thickness of the particle boards produced using the UF

Specimen ID		M1 (%)	M2 (%)	M4 (%)	M5 (%)	M6 (%)	M8 (%)
Glue type	No						
	1	34,1	17,6	62,1	47,0	29,4	69,2
	2	34,5	17,4	65,6	49,9	29,3	67,7
UF	3	32,1	17,4	64,6	50,1	30,4	68,7
	4	31,7	15,2	62,4	47,5	31,1	70,5
	5	32,6	18,1	59,7	47,2	31,5	68,4
Average (%) (X)		33,0	17,1	62,9	48,3	30,3	68,9
Standard deviation (S)		1,2	1,2	2,3	1,5	1,0	1,0

Table 7. The values of swelling in thickness of the particle boards produced using the PMDI

Specimen ID		M9 (%)	M10 (%)	M11 (%)	M12 (%)	M13 (%)	M14 (%)	M15 (%)	M16 (%)
Glue type	No								
	1	11,7	8,2	11,4	8,2	10,9	7,8	12,7	8,3
	2	12,0	8,4	9,4	8,1	10,7	8,7	12,8	8,7
PMDI	3	11,5	8,5	10,2	6,5	12,7	8,6	11,7	8,7
	4	12,0	7,9	9,8	8,1	11,0	8,6	11,7	8,8
	5	11,	9,0	10,3	7,8	10,9	8,3	11,6	8,3
Average (%)		11,7	8,4	10,2	7,7	11,2	8,4	12,1	8,5
Standard deviation (S)		0,3	0,4	0,8	0,7	0,8	0,4	0,6	0,2

The bending strength values of test samples are shown in Table 8 and Table 9. As a result of the tests, the highest bending strength value (26,64 MPa) was identified the M12 board produced using PMDI glue while the lowest bending strength value (3,6 MPa) was appeared the M4 board produced using UF glue. The bending strength values of the particle boards increased as the glue use ratio raised. Standard value was provided by only the M2 from boards produced using UF while were supplied by M10, M11, M12, M13, M14 M15 and M16 from boards produced using PMDI. In the study conducted by Bektaş et al. (2005), it was shown that the swelling value of the boards produced by using sunflower stalk particles and UF glue is 25.5%. Topbaşlı (2013) determined that the swelling values of medium density particle boards produced from banana shell wastes are between 17.7% and 44.8%.

Table 8. The bending strength values of the particle boards produced using the UF

Specimen ID							
Glue type	No	M1 (%5)	M2 (%10)	M4 (%10)	M5 (%5)	M6 (%10)	M8 (%10)
	1	10,2	18,6	3,7	7,9	10,2	4,8
	2	9,2	19,3	3,7	8,5	10,8	4,5
UF	3	8,5	18,2	3,6	7,6	9,7	4,5
	4	7,2	16,7	3,5	6,2	12,2	5,8
	5	6,7	16,8	3,5	6,5	11,0	5,1
Average (X)		8,4	17,9	3,6	7,3	10,8	4,9
Standard deviation (S)		1,4	1,1	0,0	1,0	0,9	0,5

Table 9. The bending strength values of the particle boards produced using the PMDI

Specimen ID									
Glue type	No	M9 (%5)	M10 (%10)	M11 (%5)	M12 (%10)	M13 (%5)	M14 (%10)	M15 (%5)	M16 (%10)
	1	10,62	12,48	25,17	27,02	19,14	24,48	16,42	21,87
	2	9,63	12,71	25,11	26,78	19,88	23,21	16,66	21,30
PMDI	3	10,01	12,24	23,52	24,51	20,99	22,28	16,41	20,93
	4	9,12	11,23	26,22	28,47	17,81	22,79	17,76	24,03
	5	8,98	11,90	23,67	26,43	18,17	18,70	14,90	21,48
Average (X)		9,67	12,11	24,74	26,64	19,20	22,29	16,43	21,92
Standard deviation (S)		0,67	0,58	1,13	1,42	1,29	2,17	1,02	1,23

The values of modulus of elasticity in bending of test samples are shown in Table 10 and Table 11. According to tests performed, the highest flexural modulus value (4221,6 MPa) was identified the M12 board produced using PMDI glue while the lowest flexural strength value (1156,4 MPa) was appeared the M8 board produced using UF glue. Flexural modulus values of PMDI based boards were determined higher than UF based boards. In addition, higher flexural modulus values were found in the single-layer produced particle boards. The flexural modulus value of Only the M4 and M8 from the test samples did not provide the standard value. Grigoriou (2001) determined as 11,58-32,66 MPa the bending strength values of particle boards produced using in different percentages of wood particles and wheat stalks with 10% UF, 8% PMDI, 10% UF / PMDI glues.

It was shown that bending strength values of particle boards produced using PMDI and UF/PMDI glues were higher than bending strength values of particle boards produced using UF.

Table 10. The values of modulus of elasticity in bending of the particle boards produced using the UF

Specimen ID							
Glue type	No	M1 (%5)	M2 (%10)	M4 (%10)	M5 (%5)	M6 (%10)	M8 (%10)
	1	2047,5	3046,5	1248,4	2208,4	2477,2	1167,0
	2	2042,9	3181,5	1310,1	2308,9	2601,9	1170,8
UF	3	1816,8	2982,1	1268,4	2231,6	2443,1	968,3
	4	1683,8	2728,7	1210,8	1756,7	2705,6	1235,2
	5	1502,4	2786,5	1250,8	1935,0	2603,3	1240,9
Average (X)		1818,7	2945,1	1257,7	2088,1	2566,2	1156,4
Standard deviation (S)		234,9	186,7	36,0	232,9	106,2	110,7

Table 11. The values of modulus of elasticity in bending of the particle boards produced using the PMDI

Specimen ID									
Glue type	No	M9 (%5)	M10 (%10)	M11 (%5)	M12 (%10)	M13 (%5)	M14 (%10)	M15 (%5)	M16 (%10)
	1	1850,9	2048,0	4144,3	4290,4	3535,4	3703,1	2517,0	2865,5
	2	1772,4	2100,6	4232,0	4300,2	3571,4	3656,0	2576,1	2894,2
PMDI	3	1701,0	1979,7	4258,1	4072,7	3482,3	3517,8	2488,6	2815,6
	4	1617,2	1895,9	4132,1	4210,7	3357,3	3524,7	2431,1	2885,5
	5	1592,7	1933,7	3937,6	4234,2	3418,6	3431,0	2320,9	2828,4
Average (X)		1706,8	1991,6	4140,8	4221,6	3473,0	3566,5	2466,7	2857,8
Standard deviation (S)		107,4	83,2	125,9	91,3	86,5	110,8	96,8	34,6

In Table 12 and Table 13 showed the tensile strength values of test samples. When the test results are examined, the highest tensile strength value (2,46 MPa) was determinated the M10 board produced using PMDI glue while the lowest flexural strength value (<0,xx) was appeared the M1, M4 and M5 board produced using UF glue. The increase in the amount of glue and the use of PMDI glue have increased the tensile strength value. Tensile strength values of boards produced using UF glue did not provide the standard value while tensile strength values of boards produced using PMDI glue provide the standard value.

Table 12. The tensile strength values of the particle boards produced using the UF

Specimen ID							
Glue type	No	M1(%5)	M2(%10)	M4(%10)	M5(%5)	M6(%10)	M8(%10)
	1	*	0,24			0,06	0,02
	2	*	0,33			0,03	0,03
UF	3	*	0,74			0,03	0,03
	4	*	0,25			*	0,01
	5	*	0,20			*	0,02
Average (X)		*	0,35			0,04	0,02
Standard deviation (S)		*	0,22			0,02	0,01

Table 13. The tensile strength values of the particle boards produced using the PMDI

Specimen ID									
Glue type	No	M9 (%5)	M10 (%10)	M11 (%5)	M12 (%10)	M13 (%5)	M14 (%10)	M15 (%5)	M16 (%10)
	1	1,51	2,7	0,73	0,58	1,27	1,8	1,31	2,4
	2	1,46	2,3	0,79	1,29	1,55	2,45	1,25	2,2
PMDI	3	1,40	2,7	0,49	1,30	1,12	1,7	1,36	2,7
	4	1,35	2,5	0,66	1,12	1,50	1,91	1,10	2,4
	5	1,32	2,1	0,62	1,22	1,49	2,1	0,95	2,1
Average (X)		1,41	2,46	0,66	1,10	1,41	2,00	1,20	2,4
Standard deviation (S)		0,08	0,26	0,12	0,30	0,20	0,30	0,17	0,23

In Wu (2001) study, it was measured that the tensile strength values of the boards produced by using sugar cane stalk and PMDI glue were 1,63-2,70 MPa. Furthermore, It has been shown that the perpendicular tensile strength values of the boards produced using PMDI are increased.

4. Conclusion

In this study, particle boards were produced using two different glue and two different usage rates. Furthermore, some properties of single and three layered particle boards produced by using wood particles and wheat stalks as raw materials have been examined. PMDI glue gave better results than UF glue. Physical and mechanical properties of particle boards produced using PMDI glue provided the standard values. Both the physical and mechanical properties of the particle boards increased as the amount of glue used rising.

It has been shown in this study that wheat stalks and PMDI glue can be used in particle board production. Most of the samples produced provided standard values.

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