Utilizing Poppy Husk-based Particleboards as an Alternative Material in Case Furniture Construction

Mustafa Kucuktuvek,[a] Ali Kasal,[b,]* Tolga Kuskun,[b] and Yusuf Ziya Erdil [b]

Particleboard can be defined as a wood-based panel produced under pressure and heat with the inclusion of wood particles or other lignocellulosic materials and an adhesive. The need for alternative resources to replace wood raw material has emerged. Poppy husk biomass might have a value-added opportunity, and it is possible to produce particleboards from poppy husk and other softwood species. In this study, moment capacities of L-type corner joints fabricated from poppy husk-based particleboards, which are expected to be an alternative material for case furniture, were investigated. For this purpose, particleboards with five different ratios of poppy husk (P1, P2, P3, P4, P5) were produced, and then L-type corner joints were prepared. Corner joints were connected to each other with two different joint techniques (screwed, minifixed). Specimens were tested under static tension and compression loads, which are the loads commonly experienced by joints during service. According to the results, joints constructed from P5 and connected with screws had the highest moment capacity, whereas joints constructed from P1 and connected with minifix had the lowest moment capacity. In conclusion, from a technical point of view, poppy husk-based particleboards could be utilized in case furniture manufacturing for applications that are not overstressed.

Keywords: Poppy husk; Particleboard; Agricultural residue; Bending moment capacity; Corner joints; Case furniture

Contact information: a: Gazi University, Faculty of Industrial Arts Education, Department of Industrial Technology, 06500, Teknikokullar, Ankara, Turkey; b: Muğla Sıtkı Koçman University, Faculty of Technology, Department of Wood Science and Industrial Engineering, Muğla, Turkey;
** Corresponding author: alikasal@mu.edu.tr*

INTRODUCTION

Particleboard is a wood-based board product that is created under heat and pressure with wood particles or other lignocellulosic materials and an adhesive. The need for alternative resources to replace wood has emerged. Hence, research is being conducted by both the industry and scientists to seek new sources of lignocellulosic materials. Alternative fibers, such as agricultural residues and non-wood plant fibers, could play a leading role in obtaining balance among supply and demand for the manufacturing of particleboards (Nemli and Aydin 2007). These particleboards are generally manufactured from agricultural residues including opium poppy husk (Keskin *et al.* 2015), walnut (Guru *et al.* 2008), kiwi prunings (Nemli 2003), cotton seed hulls (Gurjar 1993), rice straw-wood (Yang *et al.* 2003), vine prunings (Ozen 2009), pine cone (Buyuksari *et al.* 2010), almond shells (Guru *et al.* 2006; Pirayesh *et al.* 2013), and wood flour (Kamdem 2004).

Case furniture is one of the most important types of furniture produced and used today. It is used widely in homes and offices for storage and has become essential in maintaining order in both settings (Ho and Eckelman 1994). Medium-density fibreboard (MDF) and particleboard (PB) are the most common wood-based panel products used in manufacturing case furniture. Screw-type fasteners, especially confirmat screws, are used mainly for low quality case furniture. For high class furniture and/or solid wood furniture, glued joints or hidden connection systems are preferred. According to the research of Yuksel *et al.* (2015), it was recommended that plywood (PW), MDF, and PB be used as the panel type, and confirmat screw, minifix, and sheet metal screw be used as the fastener type to construct furniture with a higher moment capacity. Moreover, the strongest L-type corner joints were achieved by an 18-mm-thick PW and confirmat screw combination; this combination was recommended to make furniture constructions with a higher moment capacity (Yuksel *et al.* 2015).

It has been reported that the mechanical properties of corner joint construction of screwed four-member cabinets are highly dependent on the thickness and panel type when other factors (screw types, screw size, screw centers, *etc.*) are kept constant (Yuksel *et al.* 2014). One study reported on the effects of screw size on the load-bearing capacity and stiffness of five-sided furniture cases constructed from PB and MDF tested under static load, and it was found that MDF cases yielded a significantly higher load-bearing capacity than particleboard cases, but the significance of the MDF cases stiffness over particleboard cases depended on the screw diameter (Kasal *et al.* 2008). Particleboards manufactured utilizing vine pruning have relatively high thickness swelling (TS) values (Ozen *et al.* 2014). Adding paraffin during board production could easily reduce the extent of thickness swelling (Ozen *et al.* 2014). Results indicated that some properties at certain proportions of wood/pruning particles can give satisfactory values. However, some strength improvements should be made to reach the strength values given in European standards (Ozen *et al.* 2014).

Today, some composite panels are manufactured from agricultural residues. However, poppy husk has not been used in the production of composite panels. Starting to use poppy husk in composite panel manufacturing will help to meet the raw material needs. Moreover, alkaloid factory waste can be put to a higher-value use.

Poppy husk-based particleboards can be used as an alternative panel in the construction of case furniture. While there is some information available on mechanical properties of these types of panels (Keskin *et al.* 2015), there is no information about the joints constructed from these panels. Accordingly, the primary purpose of this study was to obtain practical information concerning the bending moment capacity of L-type furniture corner joints constructed from particleboard produced from poppy husk residues. The findings could then be used by furniture engineers in the design of case furniture.

EXPERIMENTAL

Experimental Design

Five ratios of poppy husk-based particleboards (P1, P2, P3, P4, and P5) and two joint techniques (screwed and minifixed) were used for static bending moment capacity testing. For each sample, five replications were made, for a total of 100 L-type corner joint specimens (50 for diagonal tension, 50 for diagonal compression). Full linear models (Model 1 and Model 2) for the two-way factorial experiments were considered to determine the effects of panel type and joint technique on the bending moment capacities of L–type corner joints under tension and compression loads. The model forms are represented by Eqs. 1 and 2, respectively,

$$TM_{ijk} = \mu_1 + A_i + B_j + (AB)_{ij} + \varepsilon_{ijk} \quad (1)$$

$$CM_{ijk} = \mu_2 + A_i + B_j + (AB)_{ij} + \varepsilon_{ijk} \quad (2)$$

where TM_{ijk}, and CM_{ijk} are the bending moment capacities of L-type joints under tension and compression, respectively (*Nm*); μ_1 and μ_2 are the population mean bending moment capacities of L-type corner joints under compression and tension loads, respectively, for all panel type-joint technique combinations (*Nm*); *A* is the discrete variable representing the effect of panel type; *B* is the discrete variable representing the effect of joint technique; (*AB*) is the effect of the two-way interactions among the two variables; ε is the random error term; *i* is the index for panel type, 1..5; *j* is the index for joint technique, 1..2; and *k* is the index for the replication, 1..5.

Manufacturing of Poppy Husk-based Particleboards

The opium poppy husk particles used in the manufacturing of particleboards were obtained from an alkaloid factory in Turkey. The opium poppy husk waste collection area is shown in Fig. 1.

Fig. 1. Opium poppy husk waste collection area in Turkey

The thickness and lengths of poppy husk particles used in the core layers were 1.5 to 3 and 10 mm, respectively, while the diameter and length of poppy husk particles used in the outer layers were 0.5 to 1.5 and 3 mm, respectively. The thicknesses, widths, and lengths of Scots pine wood particles used in the core layers are 0.25 to 0.40, 2 to 6, and 10 to 25 mm, respectively, while the diameter of Scots pine wood particles used in outer layers were 0.5 to 1.5 mm, and their lengths were 1.5 to 3 mm.

The particles were first brought up to a 3% moisture gradient in a drying kiln and then classified. The mixture of Scots pine was procured from a local commercial supplier as dried up to 3% moisture gradient. Urea formaldehyde (UF) resin was used as the adhesive. Three-layer particleboards were formed by mixing the poppy (*Papaver somniferum* Linnaeus) husk and pine wood particles in different variations. The glue was placed on each of the three layers, and the layers were pressed using a laboratory press (Hursan, T100, Turkey). First cold press and then a hot press were applied in order to manufacture the particleboard. Figure 2 summarizes the poppy husk-based particleboard manufacturing process.

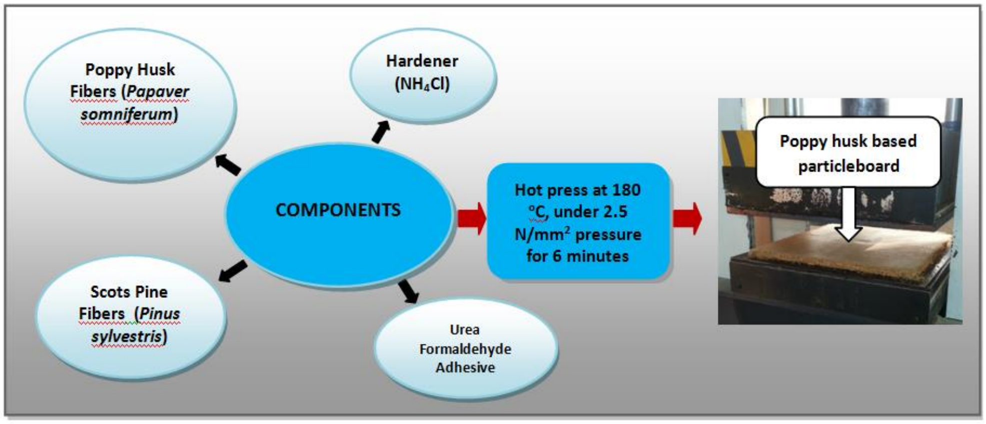


Fig. 2. Poppy husk-based particleboard manufacturing process

The thickness of the particleboards was controlled *via* stop bars. For each different formulation, five particleboards were produced. The ratios of poppy husk and pine particles of the particleboards for each formulation are given in Table 1, and the production parameters for the poppy husk-based particleboards are given in Table 2.

Table 1. Ratios of Poppy Husk and Pine Particles for the Particleboards

Panel Type	Adhesive (%)		Poppy Husk	Pine Wood
	outer	core	(%)	(%)
P1	10	8	100	0
P2	10	8	75	25
P3	10	8	50	50
P4	10	8	25	75
P5	10	8	0	100

Sources: Keskin *et al.* (2015); Kucuktuvek *et al.* (2015)

Table 2. Production Parameters for the Particleboards

Parameter	Value
Press temperature (°C)	180
Pressing time (min)	6
Hot press peak pressure (N/mm^2)	2.5
Cold press peak pressure (N/mm^2)	0.6
Thickness (mm)	18
Dimensions (mm)	500 x 500
33% NH_4Cl content (%)	2
Outer layer (whole of panel %)	34
Core layer (whole of panel %)	66
Number of panels for each type	5

Sources: Keskin *et al.* (2015); Kucuktuvek *et al.* (2015)

Physical and mechanical properties of the test panels were determined in accordance with the procedures described in ASTM D4442-92 (2001) and ASTM D1037-99 (2001). Furthermore, the withdrawal strengths of the screws from the poppy husk-based particleboards used in the corner joints were determined (Erdil *et al.* 2002; TS EN 320, 2011). The physical and mechanical properties of the poppy husk-based particleboards were taken from the study done by Keskin *et al*. (2015).

All of the specimens used in the withdrawal tests measured 150 mm^2. In the case of the edge withdrawal specimens, the screws were embedded 27 mm from the edge of the specimen, whereas in the face withdrawal specimens, the screws were embedded to the full thickness. In the edge withdrawal specimens, pilot holes were drilled at the transverse axis of the edge. Screws were inserted perpendicular to the edge of the specimen at the midpoint of the edge. Holes 12 mm in diameter were drilled through the broad face of each edge withdrawal specimen at its center to provide a point of attachment for the testing machine jig. For each specimen combination, 10 replications were performed.

Preparation of the L-type Corner Joint Specimens

The general configuration of the L-type corner joint specimens is shown in Fig. 3. The specimens consisted of two structural parts, namely, a face member and a butt member. The face part measured 270 mm long 150 mm width 18 mm thick, whereas the butt member measured 270 mm long 132 mm width and 18 mm thick.

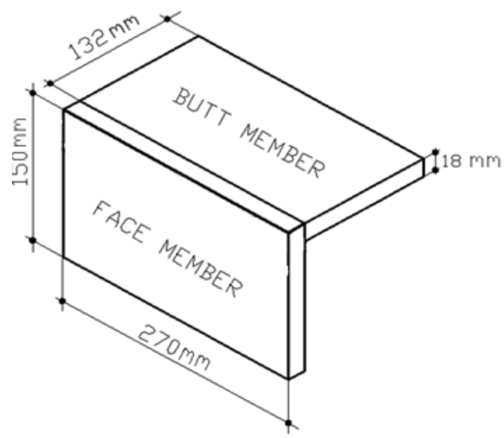
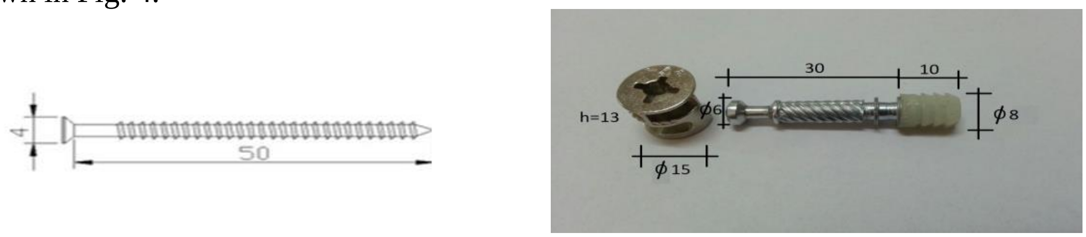


Fig. 3. General configuration of L-type corner joint specimens

Two connection techniques were utilized for assembling the L-type specimens. Half of the specimens were connected with screws, and the other half was connected with minifix fasteners.

Screw corner joints were constructed with only three screws without adhesive. The screws were 4 x 50 mm steel Phillips-head wood screws with 40±3-degree thread angles, which are the type widely used in the case furniture industry. The screw outside diameter, root diameter, and thread per mm were 4.0 ± 0.3, 2.4 ± 0.25, and 1.8 mm, respectively. The screws were driven into the transverse axis of the thickness of the butt member which had pre-drilled pilot holes. The diameters of the pilot holes were equal to 80% of the root diameter of the screws, and depths of the pilot holes were equal to 75% of the penetration of the screws (Eckelman 2003).

For the minifix joints, the members were jointed to each other with two multi-groove plastic dowels (8 mm in diameter and 30 mm in length) and three pieces of minifix. The minifix connector was placed at the longitudinal centerline of the panels. No glue was applied to the dowels. The screw and minifix fasteners used in the joints are shown in Fig. 4.



a. b.

Fig. 4. The (a) screw and (b) minifix used in the L-type corner joints

Figure 5 shows a typical placement of the screw and minifix centers in the L-type corner joints used in this study. The experimental specimens were kept in a conditioning chamber at 20± 2 °C and 65± 3% relative humidity for a month prior to testing to avoid moisture content variations.

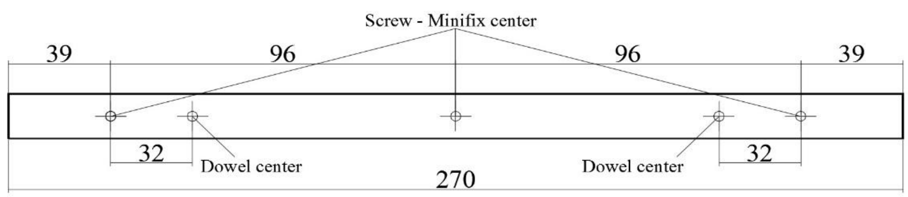
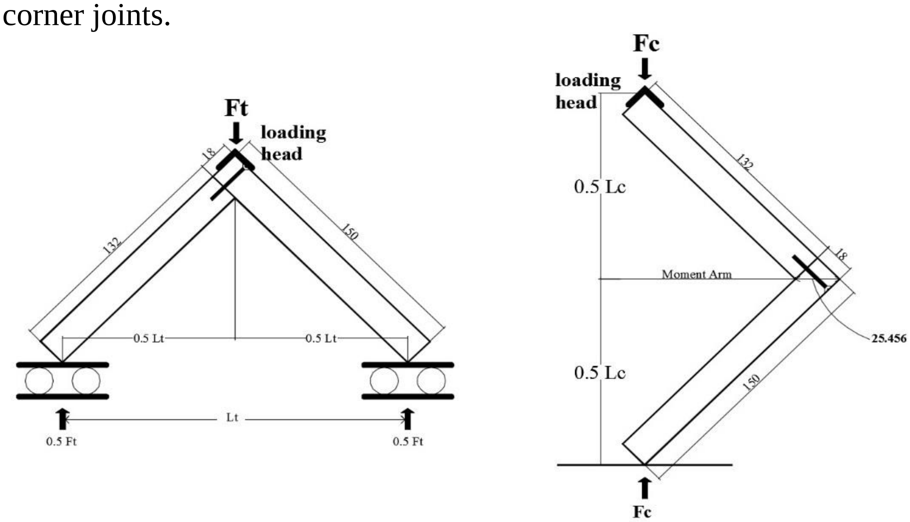


Fig. 5. Typical placement of screw, dowel, and minifix centers in the corner joints

Method of Loading and Testing

In everyday use, the corner joints of case furniture are exposed to two main forces: tension and compression. Most of these forces are applied through cantilevers (long sides) and can generate sizable bending moments. Figure 6 shows the loading diagrams that are experienced during testing corner joint moment resistances. Tension forces (Fig. 6a) tend to open the corner joints, and compression forces (Fig. 6b) tend to close the corner joints.



a. b.

Fig. 6. (a) Tension and (b) compression loading diagrams for corner joints

All of the tests were carried out using a 50-kN universal testing machine (Mares 2007, Turkey) at a loading rate of 6 mm/min.

In the tension test set-up, the edge supports of the specimen (Fig 6a) were positioned horizontally on rollers on the bed of the testing machine so that the two joint members were free to move sideways when the load was applied. In the case of the compression test, specimens were placed with the testing machine as shown in Fig 6b so that the joint was forced to close. When the load is applied in this position, the angle (90°) formed by the members joined together tends to decrease (Zhang and Eckelman 1993; Tankut and Tankut 2004).

Joint failure modes and maximum failure loads were recorded. Both tension and compression loading capacities were used to calculate the corresponding bending moment capacity. The relations between the bending moment capacity and the applied maximum failure loads under tension (F_t) and compression (F_c) were different. The bending moments were calculated using Eqs. 3 and 4,

$$M_T = 0.5F_t \times 0.5L_t \quad (Nm) \tag{3}$$

$$M_C = F_c \times \left[\sqrt{(150)^2 - (0.5L_c)^2} - 25.456 \right] \quad (Nm) \tag{4}$$

where M_T and M_C are the bending moment capacities under tension and compression loadings, respectively (Nm); F_t and F_c are the applied ultimate force of tension and compression, respectively (N); and L_t and L_c are the moment arms for tension and compression testing, respectively (m). The moment arm was calculated to be 0.09334 m for both tension and compression loadings by using a right triangle relation.

RESULTS AND DISCUSSION

Failure Modes of the Joints

Joint failures occurred in 60 s for compression tests, whereas the tension tests took 120 s. The joints opened up slowly, not suddenly. Failures of all the screwed joints started with the screw heads crushing into the face member, followed by screw withdrawal from the butt members.

The screws pulled out some core material with the edge of the member splitting around the screws. In the constructed P1 and P2 specimens, the amount of core material and the amount of edge splitting around the screws were considerably more than those of the P3, P4, and P5 panels. For the minifixed joints, failure entailed the withdrawal the screw-nut of the minifix from the face members along with some core material for all specimens.

Physical and Mechanical Properties of Poppy Husk-Based Particleboards

Some properties of the poppy husk-based particleboards used in the study are summarized in Table 3.

Table 3. Some Properties of Experimental Panels

Panel Type	Density (gr/cm^3)	Moisture Content (%)	MOR (N/mm^2)	MOE (N/mm^2)	IB (N/mm^2)	SW from face (N/mm^2)	SW from edge (N/mm^2)
P1	0.66 (1.27)*	8.93 (6.70)	3.24 (15.13)	583 (10.38)	0.21 (10.33)	4.79 (10.81)	3.63 (17.80)
P2	0.67 (1.22)	8.45 (4.23)	4.89 (10.75)	988 (8.62)	0.31 (10.17)	10.43 (5.78)	7.79 (14.45)
P3	0.68 (2.19)	8.13 (8.54)	8.15 (5.27)	1430 (4.68)	0.43 (13.47)	13.13 (14.70)	9.99 (8.88)
P4	0.69 (1.37)	8.05 (7.17)	11.28 (8.33)	1841 (8.80)	0.55 (6.58)	13.72 (5.37)	11.18 (4.27)
P5	0.70 (2.07)	7.75 (1.11)	13.70 (6.03)	2292 (6.65)	0.70 (8.07)	15.94 (8.99)	12.39 (7.31)

MOR: Modulus of rupture, MOE: Modulus of elasticity, IB: Internal bond strength, and SW: Withdrawal strength of screw. *: Values in parentheses are coefficients of variations (COV) (%).
Sources: Keskin *et al.* (2015); Kucuktuvek *et al.* (2015)

Bending Moment Capacities of the L-type Corner Joints

A two-way analysis of variance (ANOVA) general linear model procedure was performed on the bending moment capacity data (under both tension and compression) of the L-type corner joints to analyze the main effects and interactions on the mean of the bending moment capacity. MSTATC software was utilized for the statistical analyses. The ANOVA results indicated that the main factors (panel type and joint technique) and the two-factor interactions for bending moment capacity values under both tension and compression of the L-type corner joints were statistically significant at the 5% significance level. The analyses of variance results are given in Table 4 for both the tension and compression tests.

Table 4. Summary of the ANOVA Results for Tension and Compression Tests

Source	Degrees of Freedom	Sum of Squares	Mean Squares	F-Value	Prob. (Sig)
ANOVA for tension test results					
Panel type	4	24912.04	6228.01	239.12	0.0000
Joint technique	1	4150.52	4150.52	159.35	0.0000
Panel type x Joint technique	4	1806.95	451.74	17.34	0.0000
Error	10	1041.85	26.05		
Total	49	31911.35			
ANOVA for compression test results					
Panel type	4	7834.64	1958.66	164.43	0.0000
Joint technique	1	4243.05	4243.05	356.20	0.0000
Panel type x Joint technique	4	634.71	158.68	13.32	0.0000
Error	10	476.48	11.91		
Total	49	13188.88			

A least significant difference (LSD) multiple comparisons procedure at a 5% significance level was performed to determine the mean differences in bending moment capacity values under tension and compression loads of the L-type corner joints. The analysis considered the panel type, joint technique, and panel type–joint technique interactions in the ANOVA results mentioned above.

The mean comparison results based on the panel type indicated that the bending moment capacities of the joints were significantly affected by the joint member panel type. Table 5 shows the mean comparisons of the bending moment capacity values of the L-type corner joints for all panel types under both tension and compression loadings. The single LSD critical values of 4.613 and 3.120 Nm were calculated for the tension and compression tests, respectively, based on the error mean squares of the full models.

Table 5. Mean Comparisons of Ultimate Bending Moment Capacities

Panel Type	Moment under Tension		Moment under Compression	
	X (Nm)	HG	X (Nm)	HG
P1	18.31	E	13.18	E
P2	33.06	D	19.50	D
P3	40.56	C	27.10	C
P4	48.39	B	37.91	B
P5	85.07	A	47.98	A

Results indicated that the bending moment capacity of the joints considerably decreased as the poppy husk ratio increased. Increasing the poppy husk ratio from 0 (P5) to 25% (P4) decreased the bending moment capacity of the joints under tension and compression loads by approximately 43% and 21%, respectively. The joints constructed from the panels fabricated with 100% (P5) pine wood were 4.6 and 3.6 times stronger than those of the joints constructed from the panels fabricated with 100% (P1) poppy husk for tension and compression loadings, respectively. These results can be explained by differences in density and mechanical properties such as bending strength, internal bond (IB) strength, and screw withdrawal strength of the panels constructing the joints. It is a fact that the density, IB strength, and screw withdrawal strength of panels directly affect the strength properties. The panels that had a higher ratio of pine wood had a higher IB strength and withdrawal strength than the panels with a lower ratio of pine wood. This was evidenced by the joints failing by splitting. In other words, panels with higher density values, screw withdrawal strength, and IB strength would likely yield higher bending moment capacities. Generally, the poppy husk ratio had a greater effect on the bending moment capacity under tension than on the bending moment capacity under compression.

Table 6 shows the mean comparisons of the bending moment capacity values of the L-type corner joints for the two joint techniques under both tension and compression loadings. Single LSD critical values of 2.917 and 1.973 Nm were calculated for the tension and compression tests, respectively.

Table 6. Mean Comparisons of Ultimate Bending Moment Capacities

Joint Technique	Moment under Tension		Moment under Compression	
	X (Nm)	HG	X (Nm)	HG
Screw	54.19	A	38.35	A
Minifix	35.97	B	19.92	B

According to the mean comparisons, the joint technique is a very important factor for the bending moment capacity of the corner joints under both tension and compression loadings. The bending moment capacity values of the screwed and minifixed joints were 54.19 and 35.97 Nm, respectively, under tension loads and 38.35 and 19.92 Nm under compression loads. The moment capacities of the joints connected with screws were higher than those of the joints connected with minifix fasteners: 34% and 48% for tension and compression tests, respectively.

The mean bending moment capacity values under tension and compression loadings along with the LSD comparison test results for two–way interactions are given in Table 7. The single LSD values were 6.524 and 4.412 Nm for tension and compression test results, respectively.

As shown in Table 7, the P5 panels (100% pine wood) connected with screw joints had the highest bending moment capacity, whereas the joints constructed from P1 (100% poppy husk) and connected with minifix joints had the lowest bending moment capacity under both tension and compression loadings. The mean comparison results point out that increasing the poppy husk ratio tends to negatively affect the bending moment capacities of the tested corner joints under both tension and compression tests. Increasing the poppy husk ratio for each joint technique resulted in a decreased bending moment capacity of the joints. The difference between the bending moment capacities of the minifix joints constructed from P1 and P2 was not statistically significant.

Table 7. LSD Comparison Test Results for Two–Way Interactions

Joint Technique	Panel Type	Moment under Tension			Moment under Compression		
		X (Nm)	COV (%)	HG	X (Nm)	COV (%)	HG
Screw	P1	23.35	3.10	H	18.13	4.23	F
	P2	38.28	0.66	EF	26.55	3.45	D
	P3	48.35	8.72	D	34.80	4.16	C
	P4	54.94	9.20	C	52.92	8.86	B
	P5	106	10.39	A	59.34	8.12	A
Minifix	P1	13.28	21.81	I	8.24	22.22	G
	P2	27.84	1.38	GH	12.45	8.38	G
	P3	32.78	2.54	FG	19.41	3.94	EF
	P4	41.85	12.94	DE	22.89	20.00	DE
	P5	64.10	11.75	B	36.63	18.20	C

Overall, the joints subjected to tension loading yielded a mean bending moment capacity of 45.08 Nm, while the joints tested in compression loading resulted in a mean bending moment capacity of 29.14 Nm. Therefore, in general, it can be deduced that the joints loaded under tension have greater moment capacities than those loaded under compression. The bending moment capacities of the joints loaded in tension averaged 55% greater than those for the joints loaded in compression.

In a study conducted on the use of particleboards produced from vine pruning in the furniture industry, screw joint diagonal tension test results for particleboards manufactured using 25% vine pruning and 75% wood were reported as 32.70 Nm, and the diagonal compression test result was 18.05 Nm (Ozen *et al.* 2014). In the present study, for the screw joints of the particleboards manufactured using poppy husk at the same ratio, the diagonal tension and diagonal compression test results were, respectively, 68% and 193% higher. It is seen that the performance of the particleboards produced with

25% poppy husk is much higher than the particleboards produced with 25% vine pruning in terms of both mechanical properties and corner joints.

A review was made of composite panels manufactured with urea formaldehyde resin and agricultural residues. The result showed that peanut hull and European black pine mixture had similar mechanical properties with poppy husk-based panels. However, composite panels manufactured by Palm Trunk fibers exhibited lower mechanical performance than poppy husk-based panels (Chaturvedi *et al*. 2016).

Bending Moment Capacity – Poppy Husk Ratio Relations

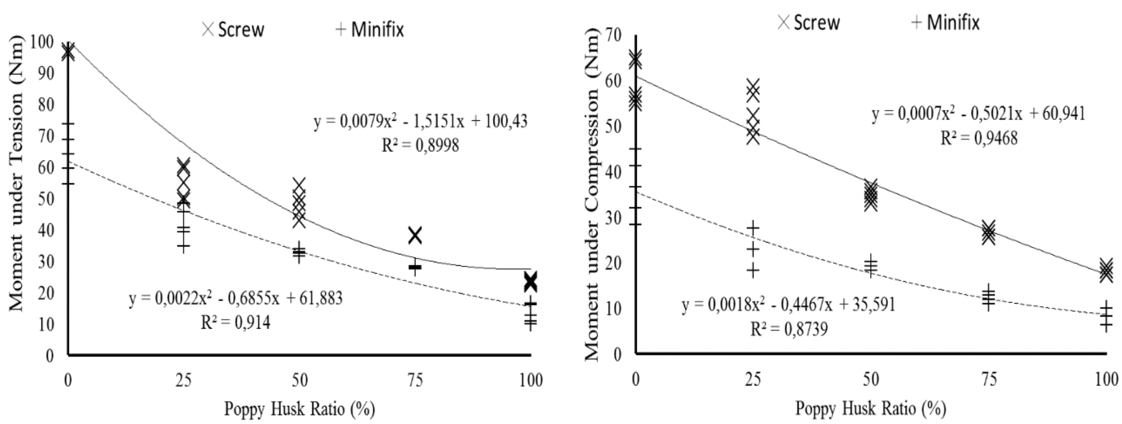
When a standard least squares regression analysis was applied to the data from the tension tests with the only variable being the ratio of poppy husk, the results indicated a curvilinear relationship between bending moment capacity and ratio of poppy husk. Likewise, according to the standard least squares regression analysis results of the data from the compression tests with the only variable being the ratio of poppy husk, the relation between the bending moment capacity and ratio of poppy husk was assumed to be a curvilinear function. The regression equations for tension and compression are represented by Eqs. 5 and 6, respectively,

$$TM_s = TM_m = aX^2 + bX + c \tag{5}$$

$$CM_s = CM_m = aX^2 + bX + c \tag{6}$$

where TM_s and TM_m are the bending moment capacities under tension for screwed and minifixed joints, respectively, (Nm); CM_s and CM_m are the bending moment capacities under compression for screwed and minifixed joints, respectively, (Nm); X is the ratio of poppy husk (%); a and b are the first and second coefficients of regression, respectively; and c is a constant term.

The tension and compression test results are given in Figs. 7 and 8, respectively, for the five poppy husk ratios.



a. b.

Fig. 7. Bending moments under tension (a) and compression (b) as a function of poppy husk ratio

The tension and compression tests data results are given in Table 8 using the least squares method by curvilinear regression. The values of the constants *a*, *b*, and *c* and the coefficients of determination (R^2) are given for each combination.

Table 8. Coefficients of Curvilinear Regressions

Loading	Joint Technique	(a)	(b)	(c)	R^2
Tension	Screw	0.0079	-1.5151	100.430	0.899
	Minifix	0.0022	-0.6855	61.883	0.914
Compression	Screw	0.0070	-0.5021	60.941	0.946
	Minifix	0.0018	-0.4467	35.591	0.874

CONCLUSIONS

This study was carried out to obtain background information concerning the bending moment capacities of L-type corner joints constructed from particleboards with various ratios of poppy husk for case furniture. The other purpose of this study was to compare the bending moment capacities of screw joints with minifix joints constructed from poppy husk-based particleboards. The following conclusions were obtained:

1. Panel type (poppy husk ratio) and joint technique both affected the moment capacities of L-type corner joints under both tension and compression loadings.
2. The bending moment capacity of L-type corner joints was affected by panel type (poppy husk ratio) under both tension and compression loadings. The bending moment capacity of L-type corner joints considerably decreased as the poppy husk ratio increased.
3. The bending moment capacities of L-type corner joints connected with screws were higher than those of joints connected with minifix fasteners.
4. L-type corner joints loaded under tension had a 55% greater bending moment capacity than those loaded under compression.
5. There were curvilinear relationships between the bending moment capacity and poppy husk ratio under both tension and compression loadings.
6. The highest bending moment capacities were obtained when the L-type corner joints were constructed from P5 (100% pine wood) and connected with screw joints.
7. Poppy husk-based particleboards can be utilized for case furniture that is not overstressed.
8. An economic comparison of poppy husk-based particleboards and conventional wood-based particleboards should be done in future studies.
9. This study introduces a new particleboard type using the poppy husk mixed or unmixed with pine particles as raw material. There are many studies related to the development of new panel products in which the agricultural residues or byproducts were utilized as raw material. More research should be conducted to better utilize new environmentally friendly bio-products or improve the properties and performance of already available ones in order to create viable alternatives to wood while making use of low value residues.

ACKNOWLEDGMENTS

The authors offer thanks to Gazi University for the manufacture of the poppy husk-based particleboards, to Muğla Sıtkı Koçman University for the test laboratories used to make the corner joints, and to Afyonkarahisar Alkaloids factory for the supply of poppy husk.

REFERENCES CITED

ASTM D1037-99 (2001). "Standard test methods for evaluating properties of wood-based fiber and particle panel materials," ASTM International, West Conshohocken, PA.

ASTM D4442-92 (2001). "Standard test methods for direct moisture content measurement of wood and wood-base materials," ASTM International, West Conshohocken, PA.

Buyuksari, U., Ayrilmis, N., Avci, E., and Koc, E. (2010). "Evaluation of the physical, mechanical properties and formaldehyde emission of particleboard manufactured from waste stone pine (*Pinus pinea* L.) cones," *Bioresour. Technol.* 101(1), 255-259. DOI: 10.1016/j.biortech.2009.08.038

Chaturvedi, R., Pappu , A., and Mishra, R. K. (2016). "Performance of formaldehyde resins and cement bonded particleboards and understanding its properties for further advancement," *International Journal of Waste Resources*. 6(2), 1-8. DOI:10.4172/2252-5211.1000215.

Eckelman, C. A. (2003). *Textbook of Product Engineering and Strength Design of Furniture*. Purdue University, West Lafayette, IN.

Erdil, Y. Z., Zhang, J., and Eckelman, C.A. (2002). "Holding strength of screws in plywood and oriented strandboard," *Forest Prod. J.* 52(6), 55-62.

Gurjar, R. M. (1993). "Effect of different binders on properties of particleboard from cotton seed hulls with emphasis on water repellency," *Bioresour. Technol.* 43(2), 177-188. DOI: 10.1016/0960-8524(93)90179-F

Guru, M., Atar, M., and Yıldırım, R. (2008). "Production of polymer matrix composite particleboard from walnut shell and improvement of its requirements," *Mater. Design* 29(1), 284-287. DOI: 10.1016/j.matdes.2006.10.023

Guru, M., Tekeli, S., and Bilici, I. (2006). "Manufacturing of urea formaldehyde-based composite particleboard from almond shell," *Mater. Design* 27(10), 1148-1151. DOI: 10.1016/j.matdes.2005.03.003

Ho, C., and Eckelman, C. A. (1994). "The use of performance tests in evaluating joint and fastener strength in case furniture," *Forest Prod. J.* 44(9), 47-53.

Kamdem, D. P., Jiang, H. H., Cui, W. N., Freed, J., and Matuana, L. M. (2004). "Properties of wood plastic composites made of recycled HDPE and wood flour from CCA-treated wood removed from service," *Compos. Part A-Appl. S.* 35(3), 347-355. DOI: 10.1016/j.compositesa.2003.09.013

Kasal, A., Zhang, J., Yuksel, M., and Erdil, Y. Z. (2008). "Effects of screw sizes on load bearing capacity and stiffness of five-sided furniture cased constructed of particleboard and medium density fiberboard," *Forest Prod. J.* 58(10), 25-32.

Keskin, H., Kucuktuvek, M., and Guru, M. (2015). "The potential of poppy (*Papaver somniferum* Linnaeus) husk for manufacturing wood-based particleboards," *Constr. Build. Mater.* 95, 224-231. DOI: 10.1016/j.conbuildmat.2015.07.160
Kucuktuvek, M., Keskin, H., and Asci, T. (2015). "Evaluation of some technologic properties of poppy husk (*Papaver Somniferum* Linnaeus) and black pine wood (*Pinus nigra* var. Pallasiana) based particleboards," in: *Proceedings of the XXVIIth International Conference Research for Furniture Industry*, Ankara, Turkey.
Nemli, G. (2003). "Suitability of kiwi prunings for particleboard manufacturing," *Ind. Crop. Prod.* 17(1), 39-46. DOI: 10.1016/S0926-6690(02)00057-2
Nemli, G., and Aydin, A. (2007). "Evaluation of the physical and mechanical properties of particleboard made from the needle litter of *Pinus pinaster* Ait," *Ind. Crop. Prod.* 26(3), 252-258.
Ozen, E. (2009). *Determination of Physical and Mechanical Properties of Panels Produced with Different Ratios of Vine Prunings/Wood Chips and Investigation of Their Moment Capacity in Furniture Corner Joints*, PhD dissertation, Gazi University Institute of Science and Technology, Ankara, Turkey.
Ozen, E., Goktaş, O., Kasal, A., Efe, H., and Demirci, S. (2014). "Bending moment capacity of l-type furniture corner joints constructed of particleboard produced from vine pruning residues," *Wood Res.* 59(2), 313-322.
Pirayesh, H., Khanjanzadh, H., and Salari, A. (2013). "Effect of using walnut/almond shells on the physical, mechanical properties and formaldehyde emission of particleboard," *Compos. Part B-Eng.* 45(1), 858-863. DOI: 10.1016/j.compositesb.2012.05.008
Tankut, A. N., and Tankut, N. (2004). "Effect of some factors on the strength of furniture corner joints constructed with wood biscuits," *Turk. J. Agric. For.* 28, 301-309 (in Turkish).
TS EN 320 (2011) "Particleboards and fibreboards - Determination of resistance to axial withdrawal of screws," Turkish Standard Institution. Turkey.
Yang, H. S, Kim, D. J, and Kim, H. J. (2003). "Rice straw-wood particle composite for sound absorbing wooden construction materials," *Bioresour. Technol.* 86(2), 117-121. DOI: 10.1016/S0960-8524(02)00163-3
Yuksel, M., Yildirim, N., Kasal, A., Erdil, Y. Z., and Demirci, S. (2014). "Effect of the panel type and panel thickness on moment resistance of screw-jointed corner joints and stiffness of four-member cabinets," *BioResources* 9(4), 6340-6349. DOI: 10.15376/biores.9.4.6340-6349
Yuksel, M., Kasal, A., Erdil, Y. Z., Acar, M., and Kuşkun, T. (2015). "Effects of the panel and fastener type on bending moment capacity of L-type joints for furniture cases," *Pro Ligno* 11(4), 426-443.
Zhang, J., and Eckelman, C. A. (1993). "Rational design of multi-dowel corner joints in case construction," *Forest Prod. J.* 43(11/12), 52-58.

Article submitted: September 6, 2016; Peer review completed: November 20, 2016; Revised version received and accepted: November 28, 2016; Published: December 6, 2016.
DOI: 10.15376/biores.12.1.839-852