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Sandwich Panels Bonded with Modified Starch**

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ABSTRACT

Aim of Study: The objective of this research was to evaluate the strength of corner joints of box shaped furniture made from eastern redcedar (*Juniperus virginiana L.*) and corn starch binder southern sample. Effectiveness of various types of corner joint techniques was evaluated (plain glued corner, glued and screwed corner, and glued with dowel corners). **Material and Methods:** Eastern redcedar (*Juniperus virginiana L.*) particle samples with corn starch were obtained from Oklahoma City, OK, and glutaraldehyde was bought from Aldrich chemicals all of which were used as experimental panels. Corner elements such as screw, glue, and dowel were obtained from Stillwater, OK. Overlaid and non-overlaid particleboards along with sandwich panels were used at L type corner joints. Tension and compression strength moment values were measured. **Main Results:** Particleboard panel joint mounted with dowel resulted in the highest tension strength moment values followed by the specimens having a sandwich-type configuration combined with a dowel. Particleboard and overlaid sandwich-type panels glued with Polyvinyl Acetate (PVAc) had the lowest strength values. **Highlights:** It appears that composite panels manufactured with modified starch would have the potential to be used for corner joints having satisfactory strength values. It seems that overlaying of the samples adversely influenced them overall corner joint strength properties.

Keywords: Eastern redcedar, Corner joint, Particleboard, Sandwich panel, Overlay, Corn starch, Diagonal tensile strength, Diagonal compression strength.

Introduction

Particleboard is one of the most common manufactured wood-based composite panels used in furniture and cabinet production. The majority of the cabinet and furniture panels are exposed to compression and tension forces during their lifespan. Depending on the magnitude of such forces deformation such as breaking, separation bending, and layering could take place in the cabinet or furniture units. Therefore, it is important to take into account such forces so that raw material and finished products could be designed with an acceptable property (Eckelman, 1985; Smardzewski, 1993). Wood and wood-based materials are important components of furniture design and furniture construction design. The advance knowledge of the behavior of such materials regarding physical and mechanical forces applied to furniture provides technical, aesthetic, and economic benefits to the designer, manufacturer, and eventually users (Imirzi et al., 2016; Efe and Kasal, 2000; Eckelman, 1978).

The type of adhesive plays a significant role in the overall joint strength of furniture units (Fatery and Williamson, 1997). It is suggested that the most effective method of building furniture and elements of wood material is by bonding the joints. Furthermore, the majority of the openings in the joints are caused by technological mistakes that occur during the gluing processes; the heterogeneous distribution of the glue on the surface is negatively affected by cohesion (Smardzewski, 2002). Simsek et al. (2010) examined the effect of end distance of cam fasteners and the number of dowels on bending moment capacity of L type furniture corner joints. Their results indicated a 60mm end distance gave as the highest moment capacity of cam connectors; two cam fasteners with the addition of 2, 3 and 4 unglued dowels were superior in terms of moment capacity.

In another study, the physical and mechanical properties of corner joints were evaluated from the perspective of tensile and compression strength. The highest and lowest tensile strength found in melamine-composite panels were 1192N and 929N, respectively. The authors concluded that, adhesives and material type influence corner joint strength (Atar et al., 2009). Bending capacities of plywood frames were assessed by Jensen and colleagues. Modules of rupture (MOR) for compression and tensile moment were 30MPa for the small cross-sections and 22MPa for the large cross-sections (Jensen, 2002).

Altinok and colleagues investigated the durability of three corner joints with melamine overlaid particleboards. Corner joint types were Polymerine PVAc spline joint, Polymerine PVAc dowel joint, spline-dowel polymerine, and PVAc combinations all of which, are used in furniture constructions. The maximum tension strength observed in PVAc combination and maximum compression strength found in polymerine combination was 27.26 Nmm² and 8.66 Nmm², respectively (Altinok et al., 2009). Altun et al. (2010) analyzed the bending moment capacity of miter frame corner joints. They used MDF as the frame material and assessed compression and tensile loads on corner joints. Results revealed that the highest bending moment capacity at diagonal tensile stress (46.09 Nm) was in cyanoacrylate (CA) glued corners. Furthermore, the highest diagonal compression stress values were found in PVAc glued corner joints (72.04 Nm).

Combination of material type with corner joint type is also important in evaluating furniture (Efe et al., 2014). "L" type furniture made from a combination of wood-based and high resistance materials are listed from highest strength to lowest: Okume plywood (OKP), fiberboard-(MDF), laminated fiberboard (MDF-L), particleboard (PB), laminated particleboard (PB-L) and OSB. The physical and mechanical properties of the above-mentioned samples have been well investigated as evident in the substantial amount of data found in the literature (Smardzewski et al., 2014; Vassiliou and Barboutis, 2009; Kasal et al., 2006; Eckelman, 2003). Furthermore, Yerlikaya and Aktas (2012) investigated the load carrying capacity of corner joints in furniture and found that the most robust joining was the combination of dowel, minifix, and fabric, whereas, the weakest joining was seen in dowel corner joints. Eastern redcedar (*Juniperus virginiana*) has a wide habitat in the State of Oklahoma and in the surrounding States. It is estimated that there is more than 4.5 million hectares of eastern redcedar and this number is projected to increase in the future (Kasemsiri et al., 2009). Large trees are popular in the furniture industry. On the contrary, eastern redcedar is underutilized due to its small size. Although eastern redcedar is generally not considered to be an important commercial species, its wood is highly valued for its durability and workability and it is widely habitant in the State of Oklahoma.

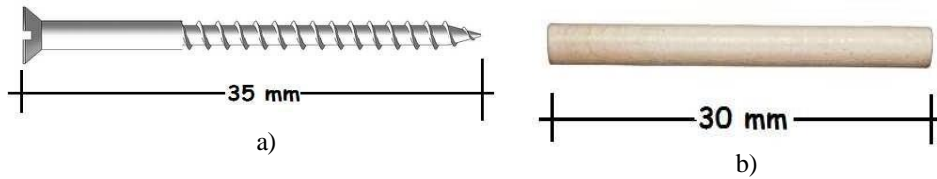
To the best of our knowledge, there is little or no information on the corner joint properties of eastern redcedar PB, overlaid eastern redcedar PB, sandwiched type panel PB, and overlaid sandwiched eastern redcedar. In this study, eastern redcedar particleboard was selected with four different types of panels. These forms were; overlaid, non-overlaid PB, overlaid PB, and non-overlaid sandwiched PB.

Materials and Methods

Sample Preparation

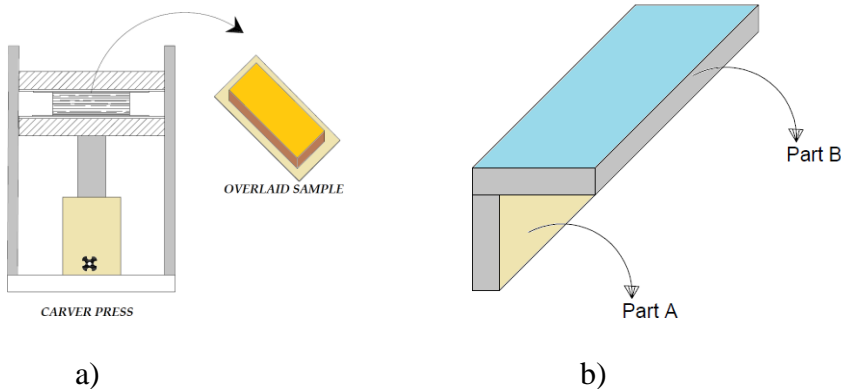
Eastern redcedar (*Juniperus virginiana L.*) particles were obtained from a local sawmill in Oklahoma City, OK. The particles contained both hardwood and softwood fractions from eastern redcedar trees. Particles were dried to 2-3% moisture content in a laboratory type oven with a 1.0m³ volume at 67±2°C for 72 hours. Dried particles were classified into two particle sizes, on a 1 and 3mm screen, namely fine and coarse, respectively. After screening, 2% urea formaldehyde (UF) and 13% corn starch glutaraldehyde were blended with particles. Experimental panels were compressed at a temperature of 180±2°C and a pressure of 5.17MPa for 5 minutes. All panels were pressed to a nominal thickness of 14mm, and their target density was 0.70 g/cm³. Panels were prepared with the dimensions of 500 X 500 X 14 (length X width X depth in mm). Wood screws were obtained from a local dealer in Stillwater, Oklahoma. For fixing L type corner joints, wooden dowels were supplied from a local shop in Stillwater, OK. A dowel of 8mm in diameter and 30mm in length that was prepared from yellow poplar was used (see Figure 1.)

Figure 1. a) *Wood Screw* b) *Wood Dowel*



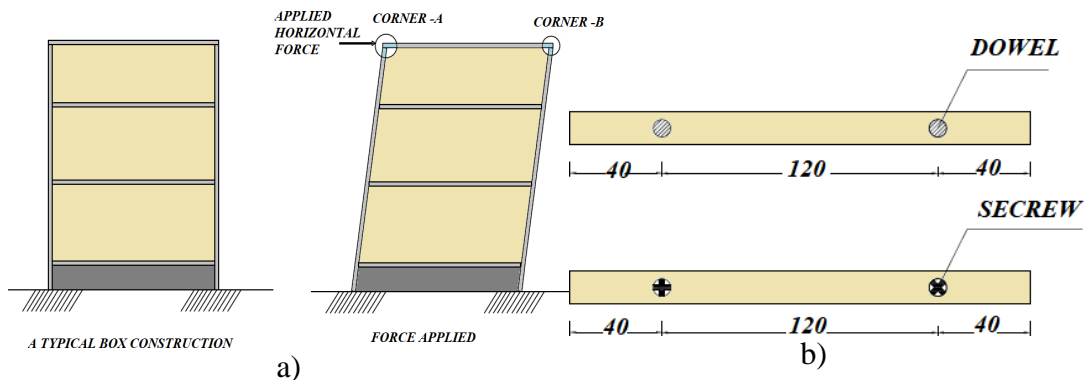
Polyvinyl acetate (PVAc) adhesive, a widely-used glue in the furniture industry was supplied from local markets and was used in the test specimens. A total of twenty (ten for each composite type) particleboards were overlaid with a melamine-based decorative paper (weight = 00165 g/cm²) with the dimensions of 200 X 100 (in mm). Particleboard samples were overlaid for the duration of 50 seconds at the Carver press with a temperature of 165°C±5°C and pressure of 2.3MPa. Prior to any surface measurements, samples were conditioned in a chamber with a temperature and a relative humidity of 20°C and 65%, respectively, until they reached to equilibrium moisture content. Overlaying process of particleboards, sandwiched panels, and the prepared test sample are depicted in Figure 2. Each experimental sample consists of two parts; part A is 20 X 8.6 X 1.4 (length X width X depth in cm), and part B is 200 X 100 X 14 (length X width X depth in mm).

Figure 2. a) *Panel Overlaying Setup* b) *L Type Construction*



Compression and tensile strength tests were carried out with one ton Comten brand series 95, Universal Testing Machine. All the tests were carried out with 2mm/min static loads in the vertical direction. Torque arm distance was calculated using $L_y = 0.0558\text{m}$ for compression and $L_x = 0.06081\text{m}$ for tensile using the right triangular connection. Corner A illustrated in Figure 3a is the diagonal pressure experiment, the moment carried under test loads, and the moments carried by each sample under diagonal tensile and compressive loads. The tensile, compressive loads, dimensions of dowels, and screws inserted in the samples are illustrated in Figure 3.

Figure 3. a) *Box Construction of Cupboard* b) *Dimensions of Inserted Dowel and Screw Sizes*



In the diagonal tensile test, the moment (M_{dt}) inserted to corner A is calculated by the following equation (see Figure 4a).

$$M_{dt} = 0.5 F_{\max Tn} \times L_x \text{ (Nm) Where;}$$

M = Moment of inertia (Nm),
 $F_{\max Tn}$ = Maximum force at the moment of displacement (N),
 L_x = Torque distance (60.81 mm),

In the diagonal compression test, the moment (M_{dp}) inserted to corner B is calculated by the following equation (see Figure 4b).

(M_{dp}) is calculated by the following equation.

$$M_{dp} = F_{\max Pr} \times L_y \text{ (Nm) Where;}$$

M_{dp} = Torque transmitted under pressure load (Nm),
 $F_{\max Pr}$ = Maximum force at retraction (N),
 L_y = Moment line (55.86 mm).

Experimental Design and Data Analysis

A total quantity of 120 samples was tested. Sixty of samples were used in compression and 60 in tension strength. Assortment of the specimens used in the test is depicted in Table 1.

Figure 4. a) *Diagonal Tensile Test Setup for Corner A (in mm)* b) *Diagonal Compression Test Setup for Corner B (in mm)*

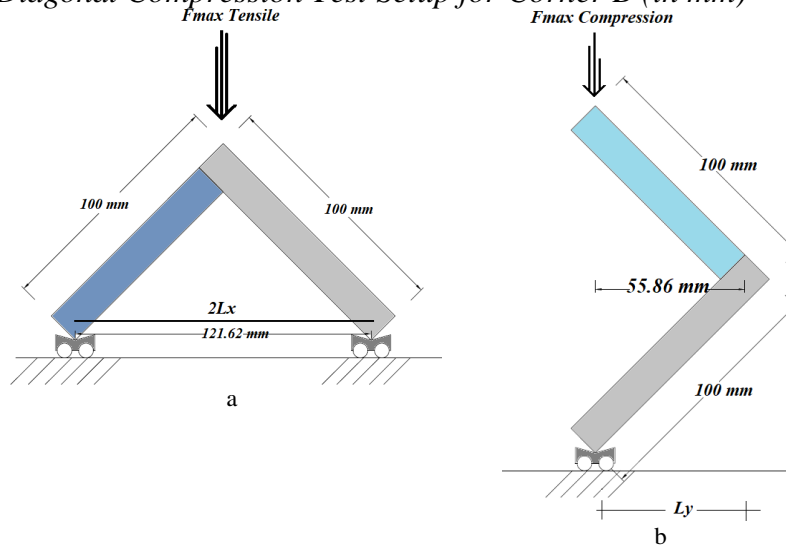


Table 1. Assortment of Tested Specimens

Material type	Overlay	Joint type	Compression	Tension
Particleboard	NON-OVERLAID	PVAc GLUE	5	5
		SCREW	5	5
		DOWEL	5	5
	OVERLAID	PVAc GLUE	5	5
		SCREW	5	5
		DOWEL	5	5
Sandwich panel	NON-OVERLAID	PVAc GLUE	5	5
		SCREW	5	5
		DOWEL	5	5
	OVERLAID	PVAc GLUE	5	5
		SCREW	5	5
		DOWEL	5	5

*In all joint types such as screw and dowel joints corners were glued with PVAc.

Prior to any experiments, samples were dried at the climatization cabin following ASTM-D 1037 guidelines. Raw data was obtained through the compression and tensile strength tests. A Two-way MANOVA was conducted to assess the significant effect of three independent variables (Material type, overlay, and joint type) on two dependent variables (compression and tension) using SPSS program, version 21.

Results

To assess the mechanical properties of various joint structures on furniture wood, two types of material (particleboard and sandwich board) was constructed. The mechanical and physical properties of the samples are given in Table 2.

Table 2. Mechanical and Physical Properties of Samples

Material type	Surface	Density (gr/cm ³)	MOR (psi)	MOE (psi)
PB*	NON-OVERLAID	0.71	1,919.50	502,512.13
	OVERLAID	0.73	1,964.36	506,325.69
SP*	NON-OVERLAID	0.81	2,091.78	514,981.36
	OVERLAID	0.82	2,209.56	529,941.28

PB* Particleboard, SP* Sandwich Board

Looking at the compression moment values and tension moment values, non-overlaid particleboards have higher values than their overlaid counterparts. However, overlaid sandwich panels showed higher values than non-overlaid panels. Values of diagonal compression and tensile strength according to corner joint types are given in Table 3.

Table 3. Diagonal Compression and Tensile Strength Moment Values

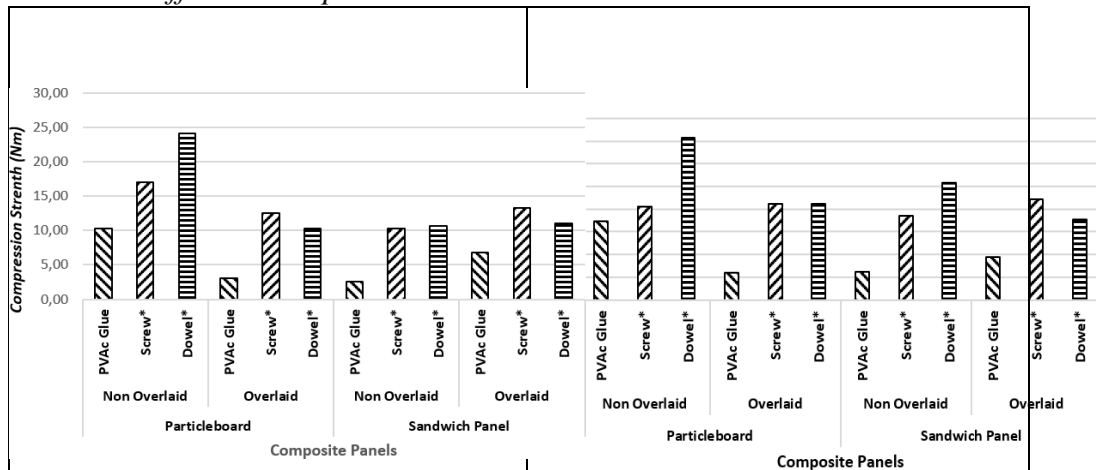
Material type	Overlay	Joint type	Compression moment values*	Tension moment values*
Particleboard	NON-OVERLAID	PVAc GLUE	10.32	17.26
		SCREW	17.04	20.54
		DOWEL	24.14	35.66
	OVERLAID	PVAc GLUE	3.07	5.98
		SCREW	12.60	21.07
		DOWEL	10.32	19.10
Sandwich panel	NON-OVERLAID	PVAc GLUE	2.61	6.26
		SCREW	10.34	18.49
		DOWEL	10.68	25.86
	OVERLAID	PVAc GLUE	6.80	9.34
		SCREW	13.34	22.19
		DOWEL	11.06	17.71

*In all joint types such as screw and dowel joints corners were glued with PVAc., all the moment values given at Nm.

Multivariate Analysis of Variance on Compression Strength Moment Values

Based on the statistical analysis, it was determined that there is a significant effect in diagonal compression strength moment values (Nm) of non-overlaid particleboard and sandwich panels samples. Overall, screwed and dowel samples of overlaid particleboards have equal diagonal compression strength moment values (Nm). With respect to overlaid sandwich panel samples, plain PVAc glued edge, dowel-PVAc samples, and screw PVAc samples have diagonal compression strength moment values of 9.34 Nm, 17.71 Nm, and 22.19 Nm, respectively. Screwed corner joint values when replaced with plain PVAc glue adhesive line, their value decreased from 22.19 Nm to 18.49 Nm. Overall diagonal compression strength moment values (Nm) of the non-overlaid samples were substantially higher at dowel joint corners. Non-overlaid corner samples had a higher diagonal compression strength moment values in particleboard and sandwich panels 12.60 and 13.34 (Nm), respectively (Figure 8).

Figure 8. *Compression Strength Moment Values and Tension Strength Moment Values in Different Composite Panels*



There was a statistically significant interaction effect between panel type and corner joint type on the compression strength moment variable with a 95% confidence level.

Table 4. *Variance Analysis according to Interactions*

Variance source	Degrees of freedom	Sum of square	Mean square	F value	P<0.05 Sig.
Panel Type*	3	804.124	268.041	116.315	0.0000
Corner Joint Type**	2	856.078	428.039	185.744	0.0000
Panel x Corner	6	187.509	31.252	13.561	0.0000
Error	48	110.614	2.304		

*Panel Types are non-overlaid eastern redcedar PB, overlaid eastern redcedar, non-overlaid sandwich panel, overlaid sandwich panel. **Corner Joint Types are plain PVAc glued, PVAc and screw and PVAc and dowel.

The Duncan test results related to the homogeneous subsets according to the values determined in this work. Homogeneity group values-A of 17.16 Nm and 13.32 Nm and 14.05 Nm were determined for panel types and corner joint types, respectively (Table 5).

Table 5. *Comparative Test Results for Compression Strength Moment Values (Nm) and Homogeneity Groups*

Parameters	Overlay	HG*A	HG*B	HG*C
Panel Type	NON-OVERLAID PB*	17.16		
	OVERLAID PB*			8.66
	NON-OVERLAID SwP*			7.87
	OVERLAID Swp*		10.39	
Joint Type	PVAc Glued		5.70	
	PVAc and Screw	13.32		
	PVAc and Dowel	14.05		

PB* Particleboard, SwP* Sandwiched Panel

Multivariate Analysis of Variance on Tensile Strength Moment Values

According to the multivariate analysis of variance, tensile strength values were affected by corner joint interactions. The effectiveness of the tensile strength moment on corner joint types of the samples, are displayed in Table 6. Based on statistical analysis, significant differences were observed between panel type and corner joint type 95% confidence level. Corner joint types were found to be effective with different panel types ($p < 0.05$) on compression strength moment values (Nm).

Table 6. *Variance Analysis according to Interactions*

Variance source	Degrees of freedom	Sum of square	Mean square	F Value	P<0.05 Sig.
Panel type	3	733.52	244.51	110.29	0.0000
Corner joint type	2	2497.02	1248.51	563.17	0.0000
Panel x Corner joint	6	631.87	105.31	47.50	0.0000
Error	48	106.41	2.21		

a Panel Types are non-overlaid eastern redcedar PB, overlaid eastern redcedar, non-overlaid sandwich panel, overlaid sandwich panel

b Corner Joint Types are plain PVAc glued, PVAc and screw and PVAc and dowel

Table 7 displays the Duncan test results related to the homogeneous subsets according to the values determined in this work. Homogeneity group values-A of 24.48 Nm and 25.08 Nm were determined for panel types and corner joint types, respectively.

Table 7. Comparative Test Results for Tensile Strength Moment Values (Nm) and Homogeneity Groups

Parameters	Overlay	HG*A	HG*B	HG*C
Panel Type	NON-OVERLAID PB*	24.48		
	OVERLAID PB*		16.04	
	NON-OVERLAID SwP*		16.86	
	OVERLAID Swp*		16.41	
Joint Type	PVAc Glued			9.71
	PVAc and Screw		20.56	
	PVAc and Dowel	25.08		

PB* Particleboard, SwP* Sandwiched Panel

Discussion

Screwed corner joints at overlaid sandwich panels have a higher compression and tensile moment values compared to eastern redcedar particleboard panels. Results of this study are comparable to Kasal's (2008) study, where MDF panels with glued-screwed corner joints were stronger than particleboard panels (Kasal, 2008).

Screwed corner joints at overlaid sandwich panels have a higher compression and tension moment values compared to eastern redcedar particleboard panels. However, non-overlaid panel corners with dowels are stronger than other corner joint types. This result is consistent with the study of bending moment capacity of L type furniture corner joints which was constructed with vine pruning residues (Ozen et al., 2014).

Conclusions

The aim of this study was to find out compression and tension moment values of particleboards and sandwiched panels which were made from eastern redcedar particles with a modified starch. Comparative test results for compression strength and tension strength values revealed that moment capacity of corner joint samples was significantly affected by composite type and fixer type (PVAc, Screw, and Dowel). The maximum moment was achieved from non-overlaid particleboards that were connected by dowels. This result can be explained that PVAc glue is easily penetrated in wood structures and that furniture made from eastern redcedar particleboards are stronger after the glue has been applied. On the other hand, minimum moment value was obtained in the overlaid particleboard samples. It is appropriate to conclude that furniture producers should avoid plain glued corner constructions during box type furniture construction. In summary, this research supports that corner joints in eastern redcedar composite panels that are bound with modified starch such as particleboard and sandwiched panels are comparable

with standard particleboards made from urea-formaldehyde or melamine - formaldehyde binders.

References

- Altınok, M., Taş, H. H., & Çimen, M. (2009). Effects of Combined Usage of Traditional Glue Joint Methods in Box Construction on Strength of Furniture. *Materials & Design*, 30(8), 3313-3317.
- Altun, S., Burdurlu, E., & Kılıç, M. (2010). Effect of adhesive type on the bending moment capacity of miter frame corner joints. *BioResources*, 5(3), 1473-1483.
- Eckelman, C. A., Strength Design of Furniture, Tim. Tech. Inc., W. Lafayette, Indiana, USA, 1978.
- Eckelman, C. A., Rabiej, R. (1985) A Comprehensive Method of Analysis of Case Furniture. *Forest Products Journal* 35(4): 62-68.
- Efe, H., Kasal, A. (2000). Tabla Tipi Kavelalı Köşe Birleştirmelerde Tutkal Çeşidinin Çekme Direncine Etkileri. *Politeknik dergisi*, 3(4), 67-72.
- Efe H., Özen E., Danacı E., Kasal A., Demirci S. (2014). Effect of Joint Technique on Moment Capacity of L-Type Furniture Corner Joints for Case Furniture Constructed. *Kastamonu University Journal of Forestry*, 14-1, 15-23.
- Fatery, K. F., Williamson, T. G., (1997) “Adhesives”, Wood Engineering and Construction, Mc Craw–Hill Inc., New York, 1-39.
- Imirzi, H. O., Ozkaya, K., & Efe, H. (2016). Determination of the strength of L-type corner joints obtained from wood-based board materials using different joining techniques. *Forest products journal*, 66(3), 214-224.
- Jensen, J. L., Sasaki, T., & Koizumi, A. (2002). Plywood Frame Corner Joints with glued-in Hardwood Dowels. *Journal of wood science*, 48(4), 289-294.
- Kasal, A. (2008). Effect of the Number of Screws and Screw Size on Moment Capacity of Furniture Corner Joints in Case Construction. *Forest products journal*, 58(6), 36.
- Özen, E., Göktas, O., Kasal, A., Efe, H., & Demirci, S. (2014). Bending moment capacity of l-type furniture corner joints constructed of particleboard produced from vine pruning residues. *Wood Research*, 59(2), 313-322.
- Simek, M., Haviarova, E., & Eckelman, C. (2010). The effect of end distance and number of ready-to-assemble furniture fasteners on bending moment resistance of corner joints. *Wood and Fiber Science*, 42(1), 92-98.
- Smardzewski, J. (2002). Strength of profile- adhesive joints. *Wood Science and Technology*, 36(2), 173-183.
- Smardzewski, S. Dziegielewski, St. (1993) Stability of Cabinet Furniture Backing Boards. *Wood Science Technology* 28: 35-44.
- Yerlikaya, N. Ç., & Aktaş, A. (2012). Enhancement of Load Carrying Capacity of Corner Joints in Case Type Furniture. *Materials & Design*, 37, 393-401.