# Mechanical Properties of Wood-plastic Composites Produced with Recycled Polyethylene, Used Tetra Pak® Boxes, and Wood Flour

Bekir Cihad Bal *

The recycling industry has developed rapidly in recent years. Paper, plastic, glass, and metals are the most recycled materials. In this study, composite boards were produced using recycled polyethylene (R-PE) mixed with used Tetra Pak® boxes (TPBs) and pine wood flour (PWF) as fillers. The ratios of TPB to wood flour used in study were 0%, 10%, 20%, 30%, and 40%. Six test groups of composites were prepared. For each group, four composite boards of dimensions 4 × 180 × 220 $mm^3$ were produced. Some of the mechanical properties of the produced boards, such as the flexural strength, flexural modulus, tensile strength, tensile modulus, elongation at break, and Shore D hardness, were determined. The data obtained showed that the flexural modulus, tensile modulus, and density increased with the wood flour content. However, the flexural strength, tensile strength, and elongation at break decreased as the wood flour content was increased. As a result, it can be said that TPBs could be used as a filler instead of wood flour in the production of wood-plastic composites.

*DOI: 10.15376/biores.17.4.6569-6577*

*Keywords: Wood-plastic composites; WPCs; Tetra Pak® box; Wood flour; Mechanical properties*

*Contact information: Kahramanmaraş Sütçü İmam University, Vocational School of Technical Sciences, Kahramanmaraş, Türkiye; *Corresponding author: bcbal@hotmail.com*

## INTRODUCTION

Wood-plastic composite (WPC) production has rapidly increased in recent decades (Hamel *et al*. 2013). In parallel with this, scientific studies on WPC materials have increased (Lu *et al.* 2000). Much scientific research has been conducted on the properties of WPC materials. In some of these previous studies, researchers focused on the effect of lignocellulosic materials on the mechanical properties of thermoplastic composites. For example, Mengeloğlu and Karakuş (2008) determined the effects of eucalyptus wood flour materials and recycled polyethylene on some of the mechanical properties of WPCs. Çavdar *et al*. (2011) investigated the utilization of tea mill waste fibers in thermoplastic composites. Mengeloğlu *et al.* (2015) and Narlıoğlu *et al.* (2018a) investigated the utilization of furniture plant waste in the production of thermoplastic composites.

In previous studies, waste materials other than wood flour and lignocellulosic materials were also used in the production of polymer-based composites. Chavooshi and Madhoushi (2013) investigated the influence of aluminum powder and medium-density fiberboard (MDF) dust on the physical and mechanical properties of polypropylene-based composites. Valente *et al.* (2011) investigated some of the mechanical properties of hybrid thermoplastic composites made from wood flour and recycled glass fibers. Some researchers evaluated the properties of different types of polymer-based composites produced with TPBs (Avella *et al.* 2009; Sanchez-Cadena *et al.* 2013; Yilgor *et al.* 2014; Bekhta *et al.* 2016; Nassef *et al.* 2018; Aranda-García *et al.* 2020; Gallego *et al.* 2020; Sujatha *et al.* 2021; Guillén-Mallette *et al*. 2021). Kaymakçı *et al*. (2012) and Ayrılmış *et al.* (2013) evaluated some of the mechanical properties of a WPC produced with TPBs and rice husk flour. They determined that the tensile and flexural strengths decreased as the TPB amount increased, whereas the tensile and flexural modulus increased with the amount of rice husk flour. In similar studies, Ebadi *et al*. (2016, 2018) investigated the effects of TPBs on the physical and mechanical properties of WPCs produced with low-density polyethylene (LDPE) and poplar wood flour. The results showed that mechanical properties, such as the tensile strength, flexural strength, tensile modulus, and flexural modulus, increased with the TPB amount. Hidalgo (2011) and Lopes and Felisberti (2006) focused on recycled LDPE and TPBs to manufacture composite board.

With the use of TPB in the production of composite boards such as decking timber or outdoor parquet, a good way will be provided for converting used beverage box into different products. However, to the best of the authors' knowledge, there has not been sufficient study of the effect of the TPB on the mechanical properties of WPC boards. In addition, some of the results obtained by researchers were different from each other. For this reason, the aim of this study was to determine the effect of the TPB amount on some of the mechanical properties of a WPC produced with used TPBs, recycled polyethylene (R-PE), and pine wood flour (PWF).

## EXPERIMENTAL

### Materials

In this study, R-PE was used to produce WPCs. Recycled polyethylene in granular form was obtained from the Vepsan Plastik Recycling Packaging Textile Trade Limited Company (Kahramanmaraş, Türkiye), as can be seen in Fig. 1-A. Pine (*Pinus nigra*) wood flour with a 40-mesh dimension was used as a filler material (Fig. 1-B). The TPBs were also collected, shredded into small pieces using a laboratory band saw, ground with a grinder (Brader 1500), and used as a filler material. The ground TPB is shown in Fig. 1-C.


**Fig. 1.** Recycled polyethylene (A), pine wood flour (B), and ground Tetra Pak® box (C)

### Preparation of Composites

The compositions of the composites are given in Table 1. The PWF and TPB powders were dried at 103 ± 2 °C. The PWF, TPB, and R-PE were then mixed to obtain a homogenous blend before processing in the extruder. Then, the blend was mixed with a single screw extruder at temperatures of 170, 185, and 200 °C. The extruded blend was taken in a rope form from the barrel exit with a nozzle diameter of 5 mm. The extruded blend in rope form was cooled in the air. The cooled blend was cut into pellets, and these pellets were ground. The ground blend was placed in a metal mold and transferred between electrical-heated plates at a temperature of 190 ± 5 °C. Non-stick baking paper was used to prevent sticking. The blend was heated, and it melted over a period of 17 min. No pressure was applied during this procedure. At the end of this duration, the mixture was removed from the heater with the metal mold and immediately placed in a cold press. A total of 2.5 kg/cm$^2$ of pressure was applied in the cold press for 5 min. The board was taken from the metal mold, and a composite board was thus obtained with the dimension of 4 × 180 × 220 mm$^3$ (thickness × width × length). Four composite boards were produced for each group. A total of 24 boards were produced for this present study. Test samples were prepared from these boards. Four test samples were cut from each board for each test. Sixteen test specimens were prepared for each test. Test samples were cut using a laboratory band saw. The edges of each test sample prepared for the tensile test were shaped with a CNC router (US Mekatronik, Ankara, Türkiye).

**Table 1.** Composition of the Composites (wt%)

| Content | Groups | | | | | |
|---|---|---|---|---|---|---|
| | A | B | C | D | E | F |
| R-PE (%) | 100 | 60 | 60 | 60 | 60 | 60 |
| PWF (%) | 0 | 0 | 10 | 20 | 30 | 40 |
| TPB (%) | 0 | 40 | 30 | 20 | 10 | 0 |

R-PE: Recycled polyethylene; PWF: Pine wood flour; and TPB: Tetra Pak® box

## Test Standards

Flexural, tensile, and harness tests were performed according to ASTM D790-15 (2016), ASTM D638-22 (2022), and ASTM D2240-15 (2021), respectively. Flexural tests were conducted using a three-point bending test procedure on an electromechanical universal testing machine (Natek 10 kN). The span length was 60 mm. The support span-to-depth ratio was 15:1. The preload was 3 N and the test speed was 5 mm/min. The test was ended when the load decreased to 80% of the maximum load. Tensile tests were conducted on dog-bone-shaped test samples (Type I), as described in ASTM D638-22 (2022). The distance between grips was 115 mm, the preload was 5 N, and the test speed was 5 mm/min. The test was ended when the test sample broke or the load decreased to 80% of the maximum load. At the end of the test, the elongation was noted as the elongation at break. Hardness tests were performed on a Shore D test device, model LD-J loyka (Shenzhen Yibai Network Technology Co., Ltd., Guangdong, China).

The SPSS 13.0 (Sun Microsystems, Inc., Santa Clara, CA, USA) statistical package program was used. The data were analyzed using a one-way analysis of variance (ANOVA), and significant differences among groups were determined by the Duncan multiple range test.

# RESULTS AND DISCUSSION

The data obtained from laboratory tests related to the density, flexural strength, and flexural modulus of the composites, as well as the one-way ANOVA P-values and Duncan test results, are listed in Table 2. The data clearly showed that the density of the composite increased with the filler (TPB or PWF) percentage. The densities of the composites test samples were in the range of 942 to 1017 kg/m$^3$. The differences between the control (group

A) and test groups (groups B through F) were statistically significant (P < 0.001). However, the differences among the test groups (B through F) were insignificant. This result was expected. Similar results were reported by other researchers (Stark and Berger 1997; Çavuş and Mengeloğlu 2017; Çavuş 2020; Bal 2022). According to Stark and Berger (1997) and Matuana and Stark (2015), the WPC has a high density because of the compression of wood cell walls under high pressure. In this instance, the density of the wood flour was similar to that of the cell walls (1.5 g/cm$^3$). As a result, as the filler ratio was increased, the density of the composite material also increased.

**Table 2.** Density Values, Flexural Test Data, ANOVA P-Values, and Duncan Test

| Tests | Units | | A | B | C | D | E | F | P-values |
|---|---|---|---|---|---|---|---|---|---|
| Density | kg/m$^3$ | **x** | **942a*** | **1002b** | **1007b** | **1010b** | **1013b** | **1017b** | P < 0.001 |
| | | ss | 9.96 | 23.84 | 21.35 | 26.10 | 24.09 | 11.91 | |
| | | | | | | | | | |
| Flexural Strength | N/mm$^2$ | **x** | **19.8d** | **19.4d** | **19.0d** | **17.2c** | **15.9b** | **13.5a*** | P < 0.001 |
| | | ss | 0.72 | 1.74 | 1.25 | 1.41 | 1.18 | 1.75 | |
| | | | | | | | | | |
| Flexural Modulus | N/mm$^2$ | **x** | **406a*** | **851b** | **877b** | **887b** | **898b** | **999c** | P < 0.001 |
| | | ss | 36.0 | 141.0 | 94.9 | 93.2 | 157.3 | 180.0 | |

x: Mean values; ss: Standard deviation; and *Lowest value, Different letters (*a, b, c) indicates significant difference by Duncan test.

The flexural strength test results for the composites are given in Table 2. The flexural strengths of the composites were in the range of 13.5 to 19.8 N/mm$^2$. The highest flexural strength was obtained from group A (control group), and the lowest flexural strength was obtained from group F. Group F contained 60% R-PE and 40% PWF. The flexural strength of group B was 19.4 N/mm$^2$. Group B contained 60% R-PE and 40% TPB. The flexural strength difference between groups A and B was insignificant. However, the flexural strength difference between groups A and F was significant (P < 0.001). The flexural strength of the composite decreased as the PWF ratio increased. Conversely, the flexural strength of the composite increased as the TPB ratio was increased. An analysis of the flexural modulus values of the composites showed that the flexural modulus increased with the PWF to TPB ratio. The flexural modulus values of all the test groups (B to F) were higher than that of the control group (group A). The highest flexural modulus value (999 N/mm$^2$) was determined for the test samples of group F. In a similar study, Ayrılmış *et al*. (2013) evaluated some of the mechanical properties of WPC produced with TPB and rice husk flour. It was determined that the flexural strength decreased as the TPB amount increased, and the flexural modulus increased with the amount of rice husk flour. In contrast, Ebadi *et al*. (2018) investigated the effect of TPB on the physical and mechanical properties of WPCs produced with LDPE and poplar wood flour. The results showed that both the flexural strength and flexural modulus increased with the TPB amount. The differences between these two studies were related to the TPB percentage and filler type (rice husk flour and poplar wood flour) used. Ayrılmış *et al*. (2013) used TPB percentages of 57%, 47%, and 37%, while Ebadi *et al*. (2018) used TPB percentages of 10%, 20%, and 30%. In addition, Ayrılmış *et al.* (2013) did not use a polymer matrix, whereas Ebadi *et al.* (2018) used LDPE at 60%. It can be seen that there were differences in terms of the flexural strength between the results of these previous studies, and the results of the present study. In the present study, the mixture was not passed through a water bath after the extruder process, unlike other studies. It can be said that the reasons for these differences existed in the production method, filler type, and amount of filler. Matuana and Stark (2015) stated that these differences may affect the mechanical properties of WPCs. In addition, according to Ayrılmış *et al*. (2013), the cellulose content of PWF is high. Therefore, the flexural and tensile moduli of the groups using PWF as a filler were higher than those using TPB.

The tensile test data of the composites and statistical analyses are given in Table 3. The tensile strengths of the test groups were smaller than that of the control group. The smallest tensile strength was determined from the test samples of group F. The differences among all the groups were statistically significant ($P < 0.001$). The filler materials used, both the TPB and PWF, reduced the tensile strength of the composite. Taking into account only groups B and F, it can be seen that the negative effect of the PWF on the tensile strength was greater than that of the TPB. The data related to the elongation at break were similar to the data for the tensile strength. The greatest elongation at break was determined for the test samples of group A. The elongation at break values of the test groups was smaller than that of the control group. The differences between the control group and test groups were significant ($P < 0.001$), and excessive. In contrast, the tensile modulus values of the test groups were greater than that of the control group. The differences between the control group and test groups were statistically significant ($P < 0.001$). However, the differences among the test groups were insignificant (excluding group F). The filler materials used, both the TPB and PWF, increased the tensile modulus of the composites. Taking into account only groups B and F, it can be seen that the positive effect of the PWF on the tensile modulus was greater than that of the TPB. In previous studies, similar results were reported for the effects of the filler material on the tensile strength, tensile modulus, and elongation at break by other researchers (Tisserat *et al*. 2014; Mengeloglu *et al*. 2015; Kada *et al.* 2016; Altuntaş *et al.* 2017a; Karakuş *et al.* 2017; Narlıoğlu *et al*. 2018b; Avcı *et al.* 2018; Çavuş 2020).

**Table 3.** Tensile Test Data for Composites, ANOVA P-Values, and Duncan Tests

| Tests | Units | | A | B | C | D | E | F | P-values |
|---|---|---|---|---|---|---|---|---|---|
| Tensile Strength | $N/mm^2$ | x | **10.0f** | **8.7e** | **8.2d** | **7.4c** | **7.0b** | **6.3a*** | P < 0.001 |
| | | ss | 0.4 | 0.5 | 0.3 | 0.4 | 0.3 | 0.6 | |
| Tensile Modulus | $N/mm^2$ | x | **237a** | **310b** | **310b** | **323b** | **327b** | **358c** | P < 0.001 |
| | | ss | 55.7 | 22.4 | 18.6 | 33.7 | 36.4 | 45.4 | |
| Elongation at Break | % | x | **271.8b** | **6.1a** | **6.1a** | **4.8a** | **4.6a** | **4.2a*** | P < 0.001 |
| | | ss | 98.2 | 0.5 | 0.6 | 0.7 | 0.6 | 0.5 | |

x: Mean values; ss: Standard deviation; and, *Lowest value, Different letters (*a, b, c) indicates significant difference by Duncan test

According to Matuana and Stark (2015), the mechanical properties of wood polymer composites comply with the rule of mixtures. Because of the lower moduli of thermoplastic materials compared to wood materials, the stiffness of a WPC generally increases as the wood flour content increases. In addition, the toughness of a WPC generally changes as a filler added. Toughness is defined as the ability of a material to absorb energy before failure under load. At the end of the tensile test of WPCs, WPCs with added filler produce a brittle fracture, and those without fillers produce a ductile fracture. This situation can be observed in the stress-strain curve of the tensile tests. Stress-strain curves of the tensile tests of the group A, B and F are shown in Fig. 2. It can be seen that the test specimens in group A exhibited much more ductile fracture properties than those in groups B and F. In addition, the test samples of group B showed more ductile fracture than that of group F.

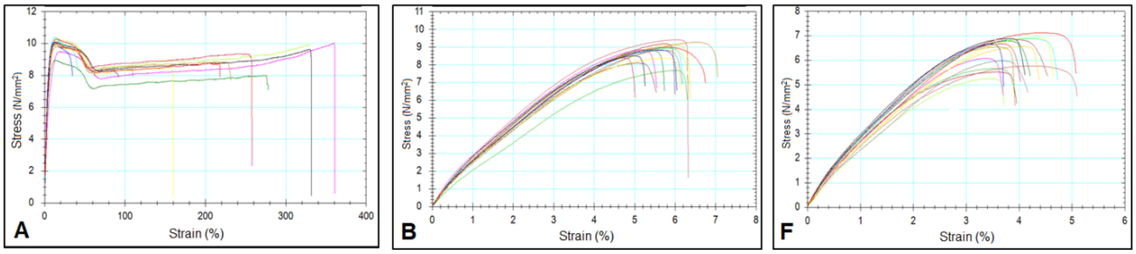


**Fig. 2.** Stress-strain curves of tensile tests of the groups A, B and F

The Shore D hardness values of the composites, ANOVA P-values, and Duncan test results are given in Table 4. The hardness values of the composites were in the range of 51.3 to 57.4. The smallest hardness was determined for the samples of group A, and the greatest hardness was determined for the samples of group F. The differences among the groups were statistically significant. The effect of using the PWF as a filler on the hardness was greater than that of the TPB. There was a strong relationship between the density and hardness, which can be observed in Table 4. In previous studies, similar results were reported by some other researchers (Altuntaş *et al.* 2017b; Çavuş and Mengeloğlu 2017; Çavuş 2020; Bal 2022).

**Table 4.** Hardness Values of Composites, ANOVA P-values, and Duncan Test

| Test | Units | | A | B | C | D | E | F | P values |
|---|---|---|---|---|---|---|---|---|---|
| Shore D Hardness | SD | **x** | **51.3a*** | **53.4b** | **54.6c** | **54.8c** | **55.4d** | **57.4e** | P < 0.001 |
| | | ss | 0.7 | 0.5 | 0.6 | 0.8 | 0.5 | 1.2 | |

x: Mean values; ss: Standard deviation; and, *Lowest value, Different letters (*a, b, c) indicates significant difference by Duncan test

## CONCLUSIONS

1. In this study, wood-plastic composite boards were successfully produced using a flat pressing method with recycled polyethylene (R-PE), used Tetra Pak® boxes (TPBs), and pine wood flour (PWF). Some of the mechanical properties of the produced composites were studied comparatively.
2. The effects of the filler type and filler percentage on the density values were significant, and the effect of the PWF was greater than that of the TPB.
3. The effects of the filler percentage on the flexural and tensile strengths were significant, and an increase in the PWF content decreased the flexural and tensile strengths, while conversely increasing the hardness.
4. The effects of the filler percentage on the flexural and tensile moduli were significant, with increases in the PWF content increasing the flexural modulus and tensile modulus, while conversely decreasing the elongation at break was observed.

## ACKNOWLEDGMENTS

This work was supported by a grant from the Kahramanmaraş Sütçü İmam University Scientific Research Projects Unit, Project Number: 2022/2-17M. I would like to thank Mr. Ümit Ayata for his contributions to the Shore D hardness tests.

## REFERENCES CITED

Altuntaş, E., Yılmaz, E., and Salan, T. (2017a). "Investigation of the effect of high-fibrous filling material on the mechanical properties of wood plastic composites," *Turkish Journal of Forestry* 18(3), 258-263. DOI: 10.18182/tjf.308969

Altuntaş, E., Yilmaz, E., Salan, T., and Alma, M. H. (2017b). "Combined effect of zinc borate and coupling agent against brown and white rot fungi in wood-plastic composites," *BioResources* 12(4), 7056-7068. DOI: 10.15376/biores.12.4.7056-7068

Aranda-García, F. J., González-Pérez, M. M., Robledo-Ortíz, J. R., Sedano-de la Rosa, C., Espinoza, K., and Ramírez-Arreola, D. E. (2020). "Influence of processing time on physical and mechanical properties of composite boards made of recycled multilayer containers and HDPE," *Journal of Material Cycles and Waste Management* 22, 2020-2028. DOI: 10.1007/s10163-020-01092-5

ASTM D790-15 (2016). "Flexural properties of unreinforced and reinforced plastics and electrical insulating materials," ASTM International, West Conshohocken, PA, USA.

ASTM D2240-15 (2021). "Standard test method for rubber property-durometer hardness," ASTM International, West Conshohocken, PA, USA.

ASTM D638-22 (2022). "Standard test method for tensile properties of plastics," ASTM International, West Conshohocken, PA, USA.

Avci, E., Acar, M., Gonultas, O., and Candan, Z. (2018). "Manufacturing biocomposites using black pine bark and oak bark," *BioResources* 13(1) 15-26. DOI: 10.15376/biores.13.1.15-26.

Avella, M., Avolio, R., Bonadies, I., Carfagna, C., Errico, M. E., and Gentile, G. (2009). "Recycled multilayer cartons as cellulose source in HDPE-based composites: Compatibilization and structure-properties relationships," *Journal of Applied Polymer Science* 114(5), 2978-2985.

Ayrilmis, N., Kaymakci, A., Akbulut, T., and Elmas, G. M. (2013). "Mechanical performance of composites based on wastes of polyethylene aluminum and lignocellulosics," *Composites Part B: Engineering* 47, 150-154. DOI: 10.1016/j.compositesb.2012.10.019

Bal, B. C. (2022). "A research on some mechanical properties of composite material produced with linear low density polyethylene (LLDPE) and wood flour," *Furniture and Wooden Material Research Journal* 5(1), 40-49. DOI: 10.33725/mamad.1126534

Bekhta, P., Lyutyy, P., Hiziroglu, S., and Ortynska, G. (2016). "Properties of composite panels made from Tetra-Pak and polyethylene waste material," *Journal of Polymers and the Environment* 24(2), 159-165. DOI: 10.1007/s10924-016-0758-7

Çavdar, A. D., Kalaycioğlu, H., and Mengeloğlu, F. (2011). "Tea mill waste fibers filled thermoplastic composites: The effects of plastic type and fiber loading," *Journal of Reinforced Plastics and Composites* 30(10), 833-844. DOI:10.1177/07316844114087

Çavuş, V., and Mengeloğlu, F. (2017). "The effect of lignocellulosic filler types and concentrations on the mechanical properties of wood plastic composites produced

with polypropylene having various melt flowing index (MFI),” *Pamukkale University Journal of Engineering Sciences* 23(8), 994-999.
Çavus, V. (2020). “Selected properties of mahogany wood flour filled polypropylene composites: The effect of maleic anhydride-grafted polypropylene (MAPP),” *BioResources* 15(2), 2227-2236. DOI: 10.15376/biores.15.2.2227-2236
Chavooshi, A., and Madhoushi, M. (2013). “Mechanical and physical properties of aluminum powder/MDF dust/polypropylene composites,” *Construction and Building Materials* 44, 214-220. DOI: 10.1016/j.conbuildmat.2013.02.079
Ebadi, M., Farsi, M., Narchin, P., and Madhoushi, M. (2016). “The effect of beverage storage packets (Tetra Pak™) waste on mechanical properties of wood–plastic composites,” *Journal of Thermoplastic Composite Materials* 29(12), 1601-1610. DOI: 10.1177/0892705715618745
Ebadi, M., Farsi, M., and Narchin, P. (2018). “Some of the physical and mechanical properties of composites made from Tetra Pak™/LDPE,” *Journal of Thermoplastic Composite Materials* 31(8), 1054-1065. DOI: 10.1177/0892705717734597
Gallego, S. M., Guzmán Aponte, Á., Buitrago Sierra, R., and Santa Marín, J. F. (2020). “Evaluation of mechanical properties of composites manufactured from recycled Tetra Pak® containers,” *Tecnura* 24(66), 36-46. DOI: 10.14483/22487638.16296
Guillén-Mallette, J., Carrillo-Baeza, J. G., Aranda-Ayala, A. A., and Rivero-Ayala, M. A. (2021). “Optimization of processability and physical and mechanical properties of extruded polyethylene-Tetra Pak cartons composites by experimental design,” *Journal of Thermoplastic Composite Materials* 34(11), 1462-1487.
Hamel, S. E., Hermanson, J. C., and Cramer, S. M. (2013). “Mechanical and time-dependent behavior of wood–plastic composites subjected to tension and compression,” *Journal of Thermoplastic Composite Materials* 26(7), 968-987. DOI: 10.1177/08927057114323
Hidalgo, M. (2011). “Manufacturing rigid board by packaging waste containing aluminum and polyethylene,” *Journal of Scientific and Industrial Research* 70, 232-234.
Kada, D., Migneault, S., Tabak, G., and Koubaa, A. (2016). “Physical and mechanical properties of polypropylene-wood-carbon fiber hybrid composites,” *BioResources* 11(1), 1393-1406. DOI: 10.15376/biores.11.1.1393-1406
Karakus, K., Basboga, İ. H., Atar, İ., and Mengeloglu, F. (2017). “Utilization of hazelnut shells as filler in LDPE/PP based polymer composites,” *Pro Ligno* 13(4), 264-268.
Kaymakcı, A., Ayrılmış, N., and Akbulut, T. (2012). “Determination of mechanical behaviour of wood polymer composites manufactured using waste aluminium polyethylene,” *Journal of History Culture and Art Research* 1(4), 334-344. DOI: 10.7596/taksad.v1i4
Lopes, C. M., and Felisberti, M. I. (2006). “Composite of low-density polyethylene and aluminum obtained from the recycling of postconsumer aseptic packaging,” *Journal of Applied Polymer Science* 101(5), 3183-3191. DOI: 10.1002/app.23406
Lu, J. Z., Wu, Q., and McNabb, H. S. (2000). “Chemical coupling in wood fiber and polymer composites: A review of coupling agents and treatments,” *Wood and Fiber Science* 32(1), 88-104.
Matuana, L. M., and Stark, N. M. (2015). “The use of wood fibers as reinforcements in composites,” in: *Biofiber Reinforcements in Composite Materials*, Woodhead Publishing, Swaston, UK, pp. 648-688.

Mengeloğlu, F., and Karakuş, K. (2008). "Some properties of eucalyptus wood flour filled recycled high density polyethylene polymer-composites," *Turkish Journal of Agriculture and Forestry* 32(6), 537-546.
Mengeloglu, F., Basboga, İ. H., and Aslan, T. (2015). "Selected properties of furniture plant waste filled thermoplastic composites," *Pro Ligno* 11(4), 199-206.
Narlıoğlu, N., Salan, T., Çetin, N. S., and Alma, M. H. (2018a). "Evaluation of furniture industry wastes in polymer composite production," *Furniture and Wooden Material Research Journal* 1(2), 78-85. DOI: 10.33725/mamad.492418
Narlıoğlu, N., Çetin, N. S., and Alma, M. H. (2018b). "Karaçam testere talaşının polipropilen kompozitlerin mekanik özelliklerine etkisi," *Mobilya ve Ahşap Malzeme Araştırmaları Dergisi* 1(1), 38-45. DOI: 10.33725/mamad.433532
Nassef, M. G., El-Galy, I., and Hassanin, A. (2018). "Mechanical and dynamic characterization of sustainable composites based on food packaging waste," *MATEC Web of Conferences* 249(2018), 1-8. DOI: 10.1051/matecconf/201824901002
Sanchez-Cadena, L. E., Alvarado-Tenorio, B., Romo-Uribe, A., Campillo, B., Flores, O., and Yao, H. (2013). "Hot-pressed boards based on recycled high-density polyethylene tetrapack: Mechanical properties and fracture behavior," *Journal of Reinforced Plastics and Composites* 32(23), 1779-1792. DOI: 10.1177/07316844134933
Stark, N., and Berger, M. J. (1997). "Effect of species and particle size on properties of wood-flour-filled polypropylene composites," in: *Proceedings of Functional Fillers for Thermoplastic and Thermosets*, San Diego, CA, USA, pp. 1-16
Sujatha, D., Mamatha, B. S., Uday, D. N., Prakash, V., Kiran, M. C., and Varada Raju K. C. (2021). "Recycling of beverages tetra pack wastes into value added composites," *International Journal of Innovative Science, Engineering and Technology* 8(1),19-28.
Tisserat, B. H., Reifschnedier, L., Núñez, J. C. L., Hughes, S. R., Selling, G., and Finkenstadt, V. L. (2014). "Evaluation of the mechanical and thermal properties of coffee tree wood flour-polypropylene composites," *BioResources* 9(3), 4449-4467.
Valente, M., Sarasini, F., Marra, F., Tirillò, J., and Pulci, G. (2011). "Hybrid recycled glass fiber/wood flour thermoplastic composites: Manufacturing and mechanical characterization," *Composites Part A: Applied Science and Manufacturing* 42(6), 649-657. DOI: 10.1016/j.compositesa.2011.02.004
Yilgor, N., Köse, C., Terzi, E., Figen, A. K., Ibach, R., Kartal, S. N., and Pişkin, S. (2014). "Degradation behavior and accelerated weathering of composite boards produced from waste Tetra Pak® packaging materials," *BioResources* 9(3), 4784-4807. DOI: 10.15376/biores.9.3.4784-4807

Article submitted: August 31, 2022; Peer review completed: September 24, 2022; Revised version received and accepted: September 29, 2022; Published: October 6, 2022.
DOI: 10.15376/biores.17.4.6569-6577