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Some selected properties of composite material produced from plastic furniture waste and wood flour

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Abstract

In this study, composite boards were produced using waste plastic furniture parts and wood flour. Wood flour was used at rates of 0%, 15%, 30% and 45% in the preparation of composite boards. Thus, 1 control and 3 composite groups were created. The boards are produced in dimensions of 3.5x175x175 mm (thickness, width, length). Density, flexural strength, flexural modulus, deformation at break, tensile strength, tensile modulus, elongation at break, hardness tests and thermal gravimetric analysis (TGA) and differential scanning calorimeter (DSC) analysis were performed on the produced composite boards. According to the obtained data, it was determined that as the percentage of wood flour in the composite groups increased compared to the control group, the values of flexural strength, deformation at break, tensile strength and elongation at break decreased whereas the values of density, hardness, flexural modulus and tensile modulus increased. According to the TGA and DSC analysis results, it was understood that the waste plastic furniture parts were composed of linear low density polyethylene (LLDPE) and polypropylene (PP) polymer materials, also the decomposition temperature of the composite materials partially increased with the increase in the percentage of wood flour.

Keywords: Waste plastic furniture, composite material, wood flour

Plastik mobilya atıkları ve odun unu ile üretilen kompozit malzemenin seçili bazı özellikleri

Öz

Bu çalışmada, atık plastik mobilya parçaları ve odun unu kullanılarak kompozit levhalar üretilmiştir. Kompozit levhaların hazırlanmasında, %0, %15, %30 ve %45 oranlarında odun unu kullanılmıştır. Böylece 1 kontrol ve 3 kompozit grubu oluşturulmuştur. Levhalar 3.5x175x175 mm (kalınlık, genişlik, uzunluk) ölçülerinde üretilmiştir. Üretilen kompozit levhaların yoğunluk, eğilme direnci, eğilmede elastikiyet modülü, kopmada deformasyon, çekme direnci, çekmede elastikiyet modülü, kopmada uzama ve sertlik testleri ile termo gravimetrik analiz (TGA) ve diferansiyel taramalı kalorimetre (DSC) analizi yapılmıştır. Elde edilen verilere göre; kontrol grubuna göre kompozit gruplarındaki odun unu yüzdesi arttıkça eğilme direnci, kopmada deformasyon, çekme direnci ve kopmada uzama değerlerinin azaldığı, buna karşılık, yoğunluk, sertlik, eğilmede elastikiyet ve çekmede elastikiyet değerlerinin arttığı belirlenmiştir. TGA ve DSC analizi sonuçlarına göre atık plastik mobilya parçalarının doğrusal alçak yoğunluklu polietilen (DAYPE) ve polipropilen (PP) polimer malzemelerden oluştuğu, ayrıca odun unu oranının artmasıyla kompozit malzemelerin bozunma sıcaklığının kısmen arttığı anlaşılmıştır.

Anahtar kelimeler: Atık plastik mobilya, kompozit malzeme, odun unu

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1 Introduction

Wooden material is a valuable material used in the production of furniture that meets many needs such as sitting, sleeping and resting with the transition of human beings to a settled life. Materials such as wood-based composites, metals, glass and plastic are also widely used in furniture production with the increase in consumption after the Industrial Revolution. Almost all of these materials can be reused. In particular, plastic materials are among the materials that can be recycled and reused. In recent years, total furniture production around the world has increased. One of the important reasons for this is that consumers' furniture renewal times have decreased compared to the past. This has led to an increase in the amount of waste furniture. Today, different methods such as recycling, reuse and incineration are used to eliminate solid wastes.

In furniture production, solid wood, wood-based composite materials, metals, glass, marble, textile products and plastic materials have been widely used from the past to present (Bal and Kılavuz 2015). Metal, glass and plastic are materials that can be recycled and reused among these materials. Plastic material is easier to recycle than other waste materials among these materials and is one of the most collected materials for recycling among solid waste.

Recycled plastic materials are used in different areas. In particular, wood plastic composite (WPC) materials are widely used today as flooring, benches, picnic tables and building exterior cladding (Stark and Matuana 2004; Smith and Wolcott 2006; Klyosov 2007). Scientific studies are carried out on recycled plastic materials. For example, Mengeloğlu and Karakuş (2008) investigated the mechanical properties of recycled high density polyethylene (rHDPE) composites obtained from wastewater pipes filled with eucalyptus wood flour in their study. Miyahara et al., (2018) studied the preparation and characterization of composite materials using plastic waste from hydrapulper from paper industries extruded with sugar cane fiber residues. Özkaya et al., (2021) determined the usage possibilities of powder rubbers obtained from waste car tires in the production of laminated veneer lumber (LVL) boards. Hukala et al., (2022) prepared and characterized the wood polymer composites consisting of used polypropylene (PP) bottles and saw dust. Bekhta et al., (2017) manufactured and determined the properties of veneer overlaid flat pressed wood plastic composite panels from recycled low density polyethylene (rLDPE), wood particles and different kinds of veneer using various adhesives. Lyutty et al., (2018) experimented the possibility of manufacture and properties of the lightweight flat pressed WPC using rLDPE, expanded polystyrene and wood particles. Rahman et al., (2018) determined the physical, mechanical and decay resistance of wood plastic composites produced from drinking water bottles (PET bottles). Bal (2022a) produced and tested composite boards using recycled polyethylene mixed with the used Tetra Pak® boxes and pine wood flour as fillers. Bal (2023a) determined some properties of wood plastic composite materials produced with recycled polyethylene, pine wood flour and glass flour.

As can be seen in previous studies, WPC material was produced from recycled plastic materials and its technological properties were investigated. One of the important differences between recycled plastic materials and pure plastic materials is the fillers and additives added during the production stage. Due to these substances, the properties of the plastic change. In this study, waste old plastic chairs and wood flour were mixed and a composite material was obtained. However, during the production of plastic chairs, calcite, talc, stabilizer, pigment etc. are added to the polymer material as a filler and its properties are changed. Therefore, it is not possible to obtain a pure polymer by recycling it. It should be taken into consideration that calcite, talc, etc. fillers have a significant impact on the quality of products produced from recycled waste polymers.

The aim of this study is to bring plastic chair waste into the economy by investigating the potential of using plastic chair waste, which has completed its service life after long-term use, in thermoplastic composite production. For this purpose, WPCs were produced by mixing wood flour and waste plastic, and then some physical and mechanical properties of WPCs were investigated.

2 Material and Method

2.1 Material

In this study, old and waste plastic chairs obtained from garbage were used as the polymer matrix. According to the differential scanning calorimeter (DSC) analysis performed in this study, it was understood that the polymer matrix contained polypropylene (PP) and linear low density polyethylene (LLDPE). Pine (*Pinus nigra*) wood saw dust was obtained from a timber workshop in Kahramanmaraş city. Saw dust was sifted and 60 mesh size was used as filler. No other additives or fillers are added to the mixture. The compositions of the composites are given in Table 1. A control group and 3 experimental groups were created.

Table 1. Composition of the composites (wt%)

	Control group	**Experimental groups**		
Content (%)	Group 1	Group 2	Group 3	Group 4
Waste plastic	100	85	70	55
Wood flour	0	15	30	45

Waste chairs were cut into small pieces (Fig 1-A) and mixed with the wood flour filler (Fig 1-B). Then, the blend was mixed with a single screw extruder at temperatures of 150, 165 and 175 °C. The mixture was taken as a thread from a 3 mm diameter nozzle at the exit of the extruder and left to cool on a table (Fig 1-C). Then, this material was crushed and small pellets were obtained (Fig 1-D). In order to obtain a homogeneous mixture, the material was processed twice in the extruder. Then, these pellets were passed through the extruder again, cooled on the table again and broken again to obtain small pellets in Fig. 1. These pellets were placed in a metal mold and transferred between an electrical-heated hot press at a temperature of 180 °C. Non-stick baking paper was used to prevent sticking. The pellets were heated and melted over a period of 12 min. At the end of this duration, the melted composites were removed from the hot press 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.

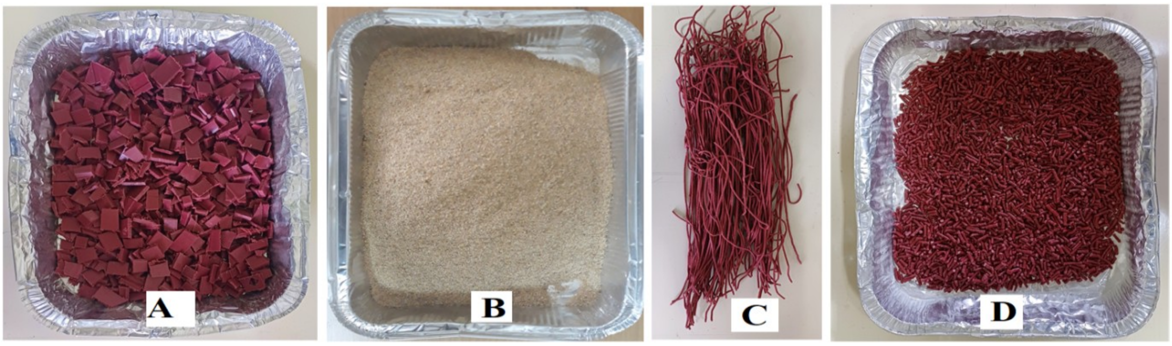

Figure 1. Waste plastic chair piece (A), Wood flour (B), The compound after extruder process (C), Pellets (D)

After pressing, the composite board was taken from the metal mold and thus a composite board was obtained with the dimension of 3.5×175×175 mm (thickness×width×length). Four composite boards were produced for each group. A total of 16 boards were produced for this present study (Fig. 2-A). 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 shapes of each test sample prepared for the tensile test (Fig. 2-B) were shaped with a CNC router. Flexural test samples were cut using a laboratory band saw in the dimensions of 3.5x20x90 mm (thickness×width×length).

Figure 2. Composite boards (A), Tensile test samples (B), Flexural test samples (C)

2.2 Method

2.2.1 Mechanical properties

Flexural tests were performed according to ASTM D790-15 (2016). Flexural tests were conducted using a three-point bending test procedure on a universal testing machine (UTM) (Fig 3). The span length was 56 mm. The support span-to-depth ratio was 16:1. The preload was 5 N and the test speed was 2 mm/min. The test was ended when the load decreased to 80% of the maximum load or test samples were broken. The amount of deformation at the end of the test is called deformation in break or deformation in bending. This value shows the deformation ability of the material against bending.

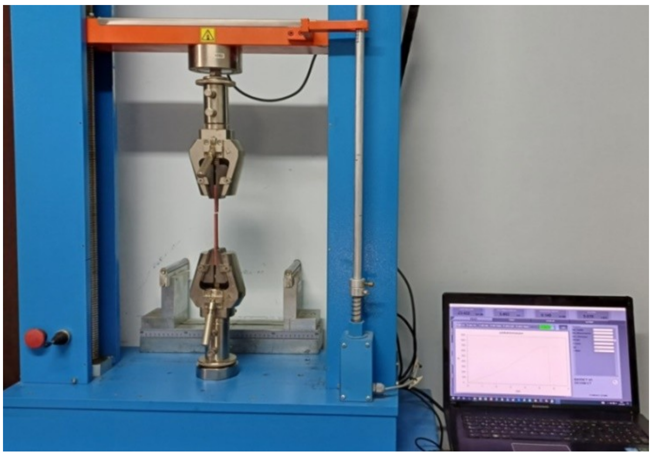

Figure 3. Testing device (UTM) for flexural and tensile tests

Tensile tests were conducted according to ASTM D638-22 (2022) on dog-bone-shaped test samples (Type-I) as described in ASTM D638-22 (2022). The distance between grips was 115 mm and the preload was 50 N. 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 according to ASTM D2240-15 (2021) on a Shore D test device. The density of the test samples was determined according to ASTM 790 (2020) by dividing the weight of the test sample by its volume in water.

2.2.2 Thermal properties

Thermogravimetric analysis (TGA) was performed using a Shimadzu TGA-50 in flowing nitrogen gas at a heating rate of 10 °C/min. The examined temperature range was between 40 °C and 600 °C. The weights of all samples were approximately 10 mg. Differential scanning calorimetry (DSC) was performed using a Shimadzu DSC-60 differential scanning calorimeter in flowing nitrogen gas at a heating rate of 10 °C/min. The scanned temperature range was between 30 °C and 200 °C. The weights of all samples were approximately 10 mg.

3 Results and Discussion

The results of density obtained from tests are given in Table 2. When the data given in the table is examined, it can be seen that the smallest density value was determined in the control group (983 kg/m^3) and the largest density value was determined in group 4 (1070 kg/m^3). The density value of the composite material also increased as the amount of filler increased compared to the control group. Differences between groups are statistically significant. Similar results were found in previous studies (Matuana and Stark 2015; Mengeloğlu et al., 2015; Çavuş 2020; Bal 2022a-b).

Table 2. Density values, ANOVA p values and Duncan test results of composite groups

Density (kg/m^3)	Group 1	Group 2	Group 3	Group 4	p values
x	983A	1002B	1045C	1070D	$p < 0.001$
ss	8.6	12.4	6.7	10.5	

Flexural test result values, ANOVA p values and Duncan test results were showed in Table 3. As can be seen in the table, the highest flexural strength value was determined in the control group and the smallest flexural strength value was determined in group 4. Differences between groups are statistically significant ($p<0.001$). As the amount of filler in the composite increased, the bending strength value decreased. Flexural strength is the ability of a composite material to stay together when it is bending. Wood flour used as a filler negatively affects the cohesion strength. In previous studies, it has been determined that bending strength decreases as the amount of filler increases regardless of the polymer material used (Berger and Stark 1997; Mengeloğlu and Karakuş 2008; Özmen et al., 2014; Matuana and Stark 2015; Mengeloğlu et al., 2015; Altuntaş et al., 2017; Narlıoğlu et al., 2018a; Bal 2022a-b).

The flexural modulus of the composites was opposite to the flexural strength values. The smallest flexural modulus value was obtained in the group 1 and the largest value in group 4. As the amount of filler in the composite material increased, the flexural modulus also increased. Differences between groups are statistically significant ($p<0.001$). Flexural modulus indicates how well a composite material resists the bending deformation. Flexural modulus of wood is higher than polymers. Therefore, flexural modulus of the composite material increases as the wood filler increases. Similar results reported in previous studies (Berger and Stark 1997; Mengeloğlu and Karakuş 2008; Mengeloğlu et al., 2015; Altuntaş et al., 2017; Narlıoğlu et al., 2018b; Bal 2022a-b).

Deformation at break values obtained from the flexural test was also given in Table 3. The highest deformation at break value was determined from group 1 and the smallest values were obtained from group 4. The differences between groups were significant ($p<0.001$). Deformation at break values shows the deformation ability of the composite material under bending force. High deformation at break values shows that the material is ductile. In contrast, low deformation at break values shows that the material is brittle. Accordingly, group 1 test samples are more ductile compared to other groups. Similar results were reported about deformation at break values by Fiore et al., (2014) and Bal (2022b).

Table 3. Flexural test data, ANOVA p values and Duncan test results

Property		Group 1	Group 2	Group 3	Group 4	p values
Flexural Strength N/mm^2	x	44.0D	38.4C	33.3B	30.7A	$p < 0.001$
	ss	2.6	1.9	1.2	0.8	
Flexural Modulus N/mm^2	x	1487A	1674B	2118C	2298D	$p < 0.001$
	ss	100	105	87	166	
Deformation at break mm	x	15.4C	9.9B	6.5A	5.2A	$p < 0.001$
	ss	3.9	1.0	0.7	0.4	

Table 4 shows the tensile strength, tensile modulus and elongation at break values as well as the Duncan test results and ANOVA p values. Tensile strength values decreased as the filler content in the composite material increased as seen in Table 4. The tensile strength of the control group was 17.5 N/mm^2 and that of group 4 was 12.1 N/mm^2. The differences among groups (group 1, group 2 and group 3) were statistically different ($p<0.001$). The effect of wood flour as a filler was negative on the tensile strength. Similar results were obtained for elongation at break. On the contrary, the effect of wood flour was positive on the tensile modulus. Tensile modulus increased as the filler content increased. The tensile modulus of group 1 was 451 N/mm^2 and tensile modulus of group 4 was 598 N/mm^2. The differences between group 4 and other groups were significant. But, there is no difference among group 1, 2 and 3. Similar results were obtained in previous studies on WPC materials filled with wood flour (Mengeloğlu and Karakuş 2008; Atar et al. 2016; Çavuş 2020; Bal 2022a-b).

Table 4. Tensile test data, ANOVA p values, Duncan test results

Property		Group 1	Group 2	Group 3	Group 4	p values
Tensile Strength N/mm^2	x	17.5C	15.3B	13.2A	12.1A	$p<0.001$
	ss	3.0	1.4	0.5	0.9	
Tensile Modulus N/mm^2	x	451A	455A	472A	598B	$p<0.001$
	ss	54	30	93	82	
Elongation at break mm	x	4.7C	4.5C	3.5B	2.6A	$p<0.001$
	ss	1.3	0.8	0.6	0.4	

Shore D hardness test values, ANOVA p values and Duncan test results were given in Table 5. When the table was analyzed, it can be seen that hardness increased with increasing wood flour content. There is a statistically significant ($p<0.001$) difference between the control group and the experimental groups but the difference between group 3 and group 4 is insignificant. Wood is a harder material than plastic. Therefore, the hardness of the composite material increases as the amount of wood flour in the composite material increases (Çavuş and Mengeloğlu 2017; Çavuş 2020; Bal 2022; Bal 2023a-b; Narlıoğlu 2021).

Table 5. Hardness test data, ANOVA p values, Duncan test results

Hardness	Group 1	Group 2	Group 3	Group 4	p values
x	72.82A	75.10B	76.13C	76.34C	$p < 0.001$
ss	1.00	0.56	0.74	0.78	

DSC curves and DSC analysis result values of the composites are given in Figure 4 and Table 6, respectively. According to Table 6 and Figure 4, it is understood that the waste plastic furniture parts are produced from 2 polymer materials. When the melting and enthalpy temperatures of the polymers are examined, it is understood that the material in the polymer is polypropylene (PP) and linear low density polyethylene (LLDPE). When Figure 4 is examined, it is understood that the material that melts at 159 °C is PP. Additionally, it was determined that the material that melts at 121 °C is LLDP polymer (Li, 2019; Dikobe 2010; Golebiewski 2007).

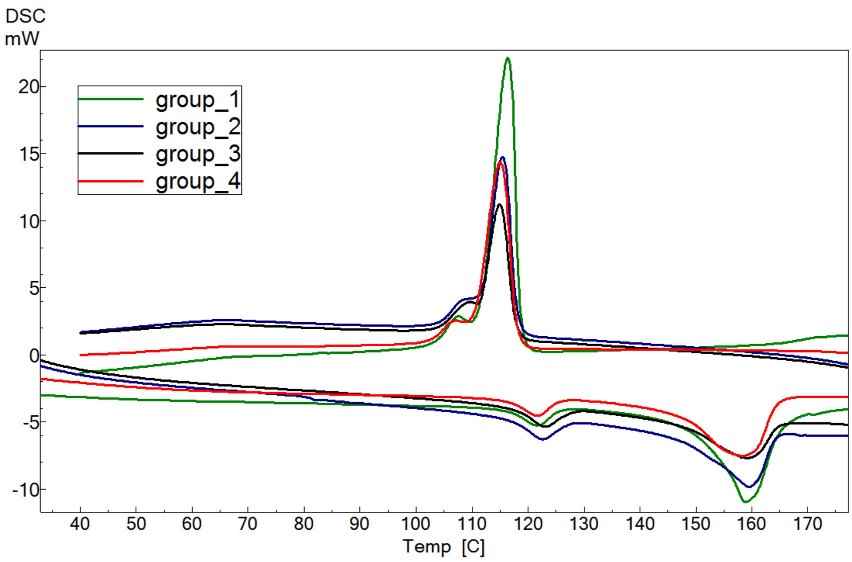

Figure 4. DSC curves of composites

It is understood that the melting temperature of LLDPE increases up to 2 °C as the amount of wood in the material increases. When Table 6 is examined, it is understood that the crystallization temperature of LLDPE varies between 107.6-110.2 °C. It has been understood that enthalpy values generally increase as the amount of wood in the composite increases. The enthalpy regions of LLDPE and PP are intertwined in Figure 4. In a study, it was stated that the enthalpies of polymers overlap each other in the DSC curve due to rapid cooling (Fonseca 1998). The DSC cooling curves of the groups are shown in Figure 4. The crystallinity degrees of the polymers are very close to each other in the composites. Therefore, crystallinity levels may be intertwined. The most likely reason for the formation of a single crystallization peak is that the polymer mixture was cooled at a relatively high rate of 10 °C min^{-1} (Dikobe ve Luyt, 2010).

Table 6. DSC analysis results of composites

Samples	LLDPE Melting Temperature (°C)	PP Melting Temperature (°C)	LLDPE Crystallization Temperature (°C)	PP Crystallization Temperature (°C)	LLDPE Crystallization Enthalpy (J/g)	PP Crystallization Enthalpy (J/g)
Group 1	121.7	159.0	107.60	116.4	1.8	64.6
Group 2	122.7	159.5	110.2	115.5	1.41	51.8
Group 3	123.7	159.3	109.8	115.0	1.41	38.6
Group 4	123.7	159.4	108.2	115.7	1.35	40.4

TGA and derivative thermal gravimetric analysis (DTGA) curves of composites were given in Figure 5. According to the TGA curves, it was understood that the degradation of composite samples with added wood occurred in 3 regions. According to the TGA curve, it was understood that wood first started to decompose at 235°C, PP at 370°C and LLDPE at 448°C. It was concluded that the lignocellulosic material was degraded in the first stage in the TGA curve and the plastic material was degraded in the second and 3rd regions. Based on a comparison with the control group, it appears that there are 2 different polymer materials within the composite material. It has been observed that polymer material decomposes between 350-500ºC especially. Wood added to composites is thought to decompose in the temperature range of 200 °C to 350°C. In a study, it was stated that the composites containing PP, LLDPE and wood had two degradation stages. First, it was understood that the wood in the composite had deteriorated. Depolymerization of lignocellulose occurred between 275°C and 350°C (Dikobe and Luyt 2010). When group 1 is examined in the TGA curves, it is understood that the amount of substance remaining at 600 ºC is approximately 12%. It is known that calcium carbonate is generally used as a filling material in the production of plastic chairs (Xanthos 2005; Srivabut et al., 2021; Aliev et al., 2023). It can be said that an inorganic substance was added to the production of the plastic chair used in this study. Additionally, the amount of remaining matter also increased at 600 ºC when wood was added to the composites.

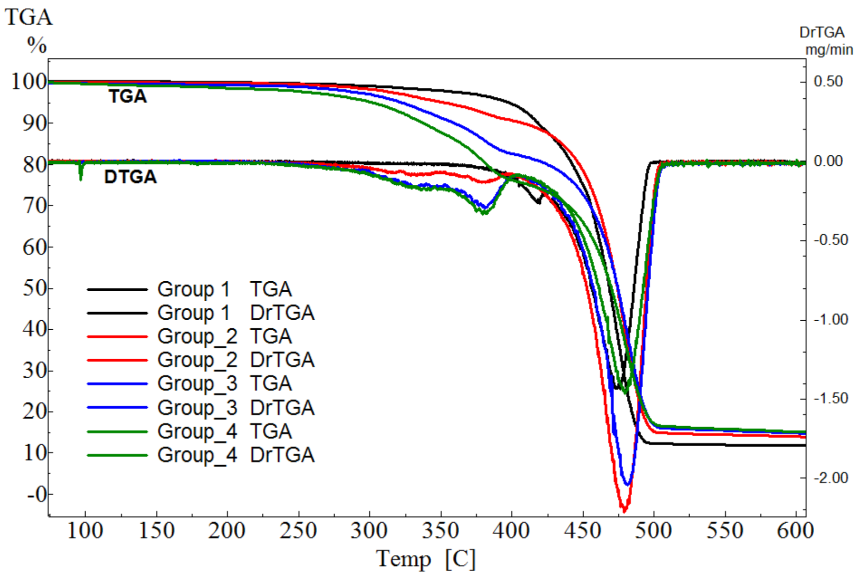

Figure 5. TGA curves of composites.

4 Conclusion

In this study, the composite material was successfully produced using waste plastic furniture parts and wood flour, and, some properties of composite material were investigated. According to the obtained data, the following results can be said;

- The density value of the composite material also increased as the amount of filler increased compared to the control group. Differences between groups are statistically significant.
- The flexural strength and deformation at break decreased as the amount of filler in the composite material increased but flexural modulus increased.
- Tensile strength and elongation at break decreased with increasing wood flour but tensile modulus increased.
- Significant increases in the hardness of the composites were observed as a result of adding wood flour to the plastic matrix compared to the control group.
- According to the thermal analysis results, it was seen that the waste plastic furniture parts consisted of two different polymers (LLDPE and PP).
- It was observed that the thermal decomposition temperature of composite materials increased partially due to the increase in the wood flour ratio in the composite.
- It has been observed that the strength values obtained in this study meet the minimum strength values required for the usage areas of polyolefin-based plastic lumber products specified in ASTM D 6662.
- The composite materials produced in this study can be used in some application areas where high rigidity is required (e.g. flooring, automobile trims) in addition to application areas that require low strength (e.g. exterior cladding, door-window frames).

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Author Contributions

Bekir Cihad Bal: Conceptualization (Developing research ideas and objectives), Data curation, Formal Analysis, Investigation, Methodology, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing., **Nasır Narlıoğlu**: Data curation, Formal Analysis, Investigation, Methodology, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Ertuğrul Altuntaş:** Data curation, Formal Analysis, Investigation, Methodology, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest statement

The authors declare no conflict of interest.

References

Aliev, S., Egamberdiev, E., Turabdjanov, S., Rashidov, S., Juraev, A. (2023). Role of fillers in the production of wood-polymer composites. In *E3S Web of Conferences* (Vol. 434, p. 02030). EDP Sciences, DOI: 10.1051/e3sconf/202343402030

Altuntaş, E., Yılmaz, E., Salan, T. (2017), 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

ASTM D 638 (2022), Standard test method for tensile properties of plastics, ASTM International, West Conshohocken, PA, 1–24 s.

ASTM D 790 (2016), Flexural properties of unreinforced and reinforced plastics and electrical insulating materials, ASTM International, West Conshohocken, Philadelphia, PA, 1–9 s.

ASTM D 792 (2004), Density and specific gravity (relative density) of plastics by displacement, ASTM International, West Conshohocken, PA, 1–11s.

ASTM D 2240 (2021), Standard test method for rubber property-durometer hardness, American Society for Testing and Materials, West Conshohocken, Pennsylvania, United States, 1–27 s.

ASTM D 6662 (2001) Standard Specification for Polyolefin-Based Plastic Lumber Decking Boards, ASTM International, West Conshohocken, PA, 1–14s.

Atar İ., Başboğa, İ. H., Karakuş, K., Mengeloğlu, F. (2016), Utilization of eggplant (Solanum melongena) stalks as a filler ın manufacturıng of compress molded PP based composites, *European Journal of Technique (EJT)*, 6(2), 138-144.

Bal, B. C., Kılavuz, M. (2015), İlk mobilya, *Selcuk University Journal of Engineering Sciences*, 14(2), 56-69.

Bal, B. C. (2022a), Mechanical properties of wood-plastic composites produced with recycled polyethylene, used Tetra Pak® boxes, and wood flour, *BioResources*, 17(4). 6569-6577, DOI: 10.15376/biores.17.4.6569-6577

Bal, B.C. (2022b), Lineer düşük yoğunluklu polietilen (LDYPE) ve odun unu ile üretilen kompozit malzemenin bazı mekanik özellikleri üzerine bir araştırma, *Mobilya ve Ahşap Malzeme Araştırmaları Dergisi*, 5(1), 40-49, DOI: 10.33725/mamad.1126534

Bal, B.C., (2023a), Comparative study of some properties of wood plastic composite materials produced with polyethylene, wood flour and glass flour, *Furniture and Wooden Material Research Journal*, 6(1), 70-79, DOI: 10.33725/mamad.1301384

Bal B.C., (2023b), Some mechanical properties of WPCs with wood flour and walnut shell flour, *Polímeros*, 33 (2)1-8, DOI: 10.1590/0104-1428.20230005

Berger, M. J., Stark, N. M. (1997), Investigations of species effects in an injection-molding-grade, wood-filled polypropylene, In The fourth international conference on woodfiber-plastic composites (pp. 19-25).

Bekhta, P., Lyutyy, P., Ortynska, G. (2017), Properties of veneered flat pressed wood plastic composites by one-step process pressing, *Journal of Polymers and the Environment*, 25(4), 1288-1295, DOI: 10.1007/s10924-016-0904-2

Çavuş, V., 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, DOI: 10.5505/pajes.2017.80000

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

Dikobe, D. G., Luyt, A. S. (2010), Comparative study of the morphology and properties of PP/LLDPE/wood powder and MAPP/LLDPE/wood powder polymer blend composites. *Express Polymer Letters*, 4(11), DOI: 10.3144/expresspolymlett.2010.88

Fiore, V., Botta, L., Scaffaro, R., Valenza, A., Pirrotta, A. (2014), PLA based biocomposites reinforced with Arundo donax fillers. *Composites Science and Technology*, 105, 110-117, DOI: 10.1016/j.compscitech.2014.10.005

Fonseca, C. A., Harrison, I. R. (1998). An investigation of co-crystallization in LDPE/HDPE blends using DSC and TREF. Thermochimica Acta, 313(1), 37-41, DOI: 10.1016/S0040-6031(97)00465-6

Golebiewski, J., Galeski, A. (2007). Thermal stability of nanoclay polypropylene composites by simultaneous DSC and TGA. *Composites Science and Technology*, 67(15-16), 3442-3447, DOI: 10.1016/j.compscitech.2007.03.007

Klyosov, A.A. 2007. Wood-plastic composites. John Wiley & Sons, Inc., Hoboken, New Jersey, 720s, DOI: 10.1002/9780470165935

Li, D., Zhou, L., Wang, X., He, L., Yang, X. (2019). Effect of crystallinity of polyethylene with different densities on breakdown strength and conductance property. Materials, 12(11), 1746, DOI: 10.3390/ma12111746

Lyutyy, P., Bekhta, P., Ortynska, G. (2018). Lightweight flat pressed wood plastic composites: Possibility of manufacture and properties. *Drvna industrija*, 69(1), 55-62, DOI: 10.5552/drind.2018.1746

Matuana, L. M., 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, DOI: 10.1533/9781782421276.5.648

Mengeloğlu, F., 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., Aslan, T. (2015). Selected properties of furniture plant waste filled thermoplastic composites, *Pro Ligno*, 11(4), 199-206.

Miyahara, R. Y., Melquiades, F. L., Ligowski, E., Santos, A. D., Fávaro, S. L., Antunes Junior, O. D. R. (2018). Preparation and characterization of composites from plastic waste and sugar cane fiber. *Polímeros*, 28, 147-154, DOI: 10.1590/0104-1428.12216

Narlıoğlu, N., Salan, T., Çetin, N. S., 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., Alma, M. H. (2018b). Effect of black pine sawdust on the mechanical properties of polypropylene composites, *Furniture and Wooden Material Research Journal* 1(1), 38-45, DOI: 10.33725/mamad.433532

Narlıoğlu, N. (2021). Evaluation of hornbeam (*Carpinus betulus* L.) wood sanding dust in thermoplastic composite production. *Furniture and Wooden Material Research Journal*, 4(1), 9-18, DOI: 10.33725/mamad.1114080

Nukala, S. G., Kong, I., Kakarla, A. B., Tshai, K. Y., Kong, W. (2022). Preparation and characterisation of wood polymer composites using sustainable raw materials. *Polymers*, 14(15), 3183, DOI: 10.3390/polym14153183

Özkaya, K., Dizel, T., Imirzi, H. Ö. (2021). Study of effect of waste tire rubber which is a recycling material in production of laminated veneer lumber (LVL) boards. *Progress in Rubber, Plastics and Recycling Technology*, 37(4), 412-421, DOI: 10.1177/14777606211019408

Özmen, N., Çetin, N. S., Narlıoğlu, N., Çavuş, V., Altuntaş, E. (2014). MDF atıklarının odun plastik kompozitlerin üretiminde değerlendirilmesi. *SDÜ Orman Fakültesi Dergisi*, 15, 65-71.

Rahman, S., Islam, M. N., Ratul, S. B., Dana, N. H., Musa, S. M., Hannan, M. O. (2018). Properties of flat-pressed wood plastic composites as a function of particle size and mixing ratio. *Journal of Wood Science*, 64(3), 279-286, DOI: 10.1007/s10086-018-1702-3

Srivabut, C., Ratanawilai, T., Hiziroglu, S. (2021). Statistical modeling and response surface optimization on natural weathering of wood–plastic composites with calcium carbonate filler. *Journal of Material Cycles and Waste Management*, *23*(4), 1503-1517, DOI: 10.1007/s10163-021-01230-7

Stark, N.M., Matuana, L.M. 2004. Surface chemistry and mechanical property changes of wood-flour/high-density-polyethylene composites after accelerated weathering. *Journal of Applied Polymer Science,* 94(6): 2263-2273, DOI: 10.1002/app.20996

Smith, P.M. Wolcott, M.P. 2006. Opportunities for wood/natural fiber-plastic composites in residential and industrial applications. *Forest Products Journal,* 56(3): 4-11.

Xanthos, M. (2005). Calcium carbonate. *Functional Fillers for Plastics. Wiley-VCH Verlag GmbH & Co. KGaA*, 271-284, DOI: 10.1002/3527605096