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Evaluation of furniture industry wastes in polymer composite production

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Abstract

In this study, composite materials were produced by using PVC polymer matrix along with medium density fiberboard (MDF) waste and massive timber waste remained from the furniture industry. For the production of composite materials, each waste material was mixed with PVC polymer and then, they were converted into pellets by using a twin screw extruder and combined pelletizer. The obtained pellets were molded into composite boards in 250 x 250 x 2 mm dimensions via hot press molding technique. The mechanical properties of the produced composites were compared with each other and with pure PVC based board in order to determine whether they can be used in various applications. The result of the mechanical tests showed that the tensile strength value of 10% wood flour-added PVC composites had the highest tensile strength value of 24.51 MPa. On the other hand, the highest bending strength value of 61.20 MPa was found for composite material with 10% MDF powder.

Keywords: Furniture industry wastes, composite material, PVC, MDF, mechanical properties

Mobilya endüstrisi atıklarının polimer kompozit üretiminde değerlendirilmesi

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Öz

Bu çalışmada, PVC polimer matrisi ile mobilya endüstrisi atıklarından orta yoğunluklu lif levha (MDF) ve masif kereste atıkları kullanılarak kompozit malzemeler üretilmiştir. Kompozit malzemelerin üretimi için her bir atık malzeme PVC polimeri ile çift vidalı bir ekstruder ve peletleyici kullanılarak pelet haline getirilmiştir. Elde edilen pelletler, sıcak pres kalıplama tekniği ile 250x250x2 mm boyutlarında kompozit levhalar haline getirilmiştir. Kompozitlerin çeşitli uygulamalarda kullanılıp kullanılamayacaklarını belirlemek için yapılan testler ile elde edilen kompozitlerin birbirleriyle ve saf PVC ile mekanik özellikleri karşılaştırılmıştır. Mekanik testlerin sonucu %10 odun unu katkılı PVC kompozitlerin çekme mukavemeti değerinin 24.51 MPa ile en yüksek çekme dayanım değerine sahip olduğunu göstermiştir. Öte yandan en yüksek eğilme direnci değeri, %10 MDF tozu katkılı kompozit malzemede 61.20 MPa bulunmuştur.

Anahtar kelimeler: Mobilya endüstrisi atıkları, kompozit malzeme, PVC, MDF, mekanik özellikler

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1 Introduction

With the widespread use of natural fiber-reinforced composite products in recent times, sawmill waste left in the lumber mills after mowing and fiberboard waste used in the furniture factories became an important raw material for the production of composite materials. These raw materials can be evaluated in composite production after they are completely dried and classified according to their type, class and size.

By evaluating recyclable materials in composite production, natural fiber-reinforced composites can be considered as eco-friendly materials. Wood plays an important role in the production of thermoplastic composites reducing the production costs in comparison with pure polymer-based products. The wood-based fibers used composites are usually obtained from sawdust waste that is occurred during timber production or from the recycling of wood-based products (such as solid wood, fiber and particleboard). Because raw wood is generally cheaper than plastics, it contributes to producers who use plastics as raw material or thermoplastic composite manufacturers lowering the production costs (Klyosov 2007, Schwarzkopf and Burnard 2016).

When the coniferous timber logs are turned into the timber and the final product, 30-40% of wood or timber generally appears as a waste. Residues are generally used for energy production or heating purposes in underdeveloped and developing countries. In the case of developed countries, these wastes are used in the production of particleboard, fiberboard or paper pulp in integrated plants (Sofuoğlu and Kurtoğlu2006). On the other hand, it was reported that the percentage of wastes occurred during the production and use of particleboard and fiberboard was between 5% and 25% (Bromhead 2003).

When thermoplastic polymers are heated, the polymer chains are separated and shifted on each other and thus, they can be easily reprocessed. High-density polyethylene (HDPE), polypropylene (PP) and polyvinyl chloride (PVC) are the most common thermoplastic polymers used in natural fiber reinforced composites (Klyosov 2007). HDPE accounts for the majority of the thermoplastics used in natural fiber reinforced composites (83%) followed by PP (9%) and PVC (7%), respectively (Caulfield et al. 2005).

Thermoplastics are useful for the production of natural fiber reinforced composites because the thermal degradation temperature of the wood is above the composite processing temperatures of 180-200 °C. In addition, these polymers can be cut, screwed and formed in various forms using grinders, crushers and sieves (Schwarzkopf and Burnard 2016).

In this study, it was aimed to produce composite materials by using PVC polymer matrix along with sawdust and MDF (Medium Density Fiberboard) powder wastes obtained from furniture factories.

2 Experimental Procedure

In this study, two different types of filling material consisting of sawdust wastes of black pine (*Pinus nigra* subsp.) from a lumber mill and MDF waste powder were used. On the other hand, PVC (GPC-K65) was used as the polymer matrix and lead stearate was used as the thermal stabilizer. Wood sawdust and MDF waste were sieved separately and the parts over 60 mesh size were taken. Then, they were dried in a furnace at 103 ± 2 °C and then kept in a desiccator containing phosphorus pentoxide until the temperature reached room temperature. In this study, a total of 10 composite mixtures were obtained by adding 10-50% of wood sawdust and MDF waste powder into the PVC polymer matrix separately (Table 1).

Table 1. Composition ratios of composites materials

ID	Ligno cellulosics (%)	Polymer (%)	Additives (%)
C	-	PVC (97)	
W1	Black pine (10)	PVC (87)	
W2	Black pine (20)	PVC (77)	
W3	Black pine (30)	PVC (67)	
W4	Black pine (40)	PVC (57)	
W5	Black pine (50)	PVC (47)	$PbSt_2$ (3)
MDF1	MDF powder (10)	PVC (87)	
MDF2	MDF powder (20)	PVC (77)	
MDF3	MDF powder (30)	PVC (67)	
MDF4	MDF powder (40)	PVC (57)	
MDF5	MDF powder (50)	PVC (47)	

Mixtures of wood flour and MDF powder in different weight ratios (10-50%) were mixed homogeneously in a mixer. Then each mixture was extruded with GULNAR brand twin screw extruder at 100 rpm and then pelletized in an automatic pellet machine with an average size of 3-5 mm. After the pellets were dried at 103 ± 2 °C, they were allowed to cool to room temperature in a desiccator containing phosphorus pentaoxide. Then composite boards were obtained according to ASTM D4703 standards from the pellets obtained with extrusion. The boards were produced using a press temperature of 185 °C and a pressure of 9 tons/m^2.

Test specimens were prepared from the resulting composites according to the relevant standard for the tensile, flexural, and impact strength tests. Composite specimens were conditioned at 65 ± 5% relative humidity and 23 ± 2 °C for one week before being subjected to mechanical testing. Tensile, flexural, and impact strength tests were performed to determine the mechanical properties of composites according to ASTM D790, ASTM D638, and ASTM D256 standard, respectively. Ten test samples were used for each mechanical test.

3 Results and Discussion

Figure 1 shows the tensile strength values of the wood flour-added PVC composites. The tensile strength values of the composites gradually decreased with the addition of wood flour into the PVC matrix. The highest tensile strength value was determined as 24.51 MPa for 10% wood flour-added PVC composite sample, while the lowest tensile strength was found as 14.03 MPa for 50% wood flour-added PVC composite sample.

Sombatsompop et al. (2003) investigated the use of wood sawdust as a filler in PVC and the effects of sawdust content on mechanical properties along with several structural and thermal changes. Generally, they found that all mechanical properties decreased with the increasing sawdust content in a very similar trend. The addition of sawdust had a more pronounced effect on the tensile properties at concentrations below 16.7 wt%. Beyond these concentrations, the tensile properties were affected to a lower extent by the sawdust content.

The tensile strength values of MDF powder-added PVC composites were given in Figure 2. Addition of MDF powder into the PVC matrix resulted in a decrease in the tensile strength values of the composites. For these values, any statistical correlation was found between the MDF powder ratio and the tensile strengths. It has been found that 10% and 40% MDF powder-added composites from MDF powder-added composites exhibited the highest tensile strength values with statistically similar values.

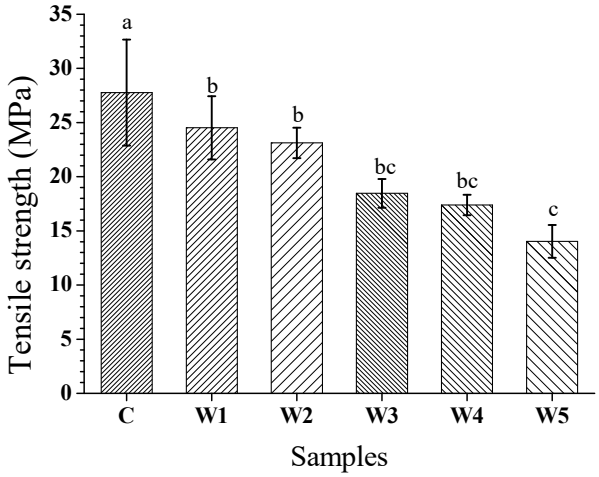

Figure 1. Tensile strength values of wood flour-added PVC composites

It was also found that composites with 20% and 50% MDF powder have the lowest tensile strength values and they were statistically similar. The highest tensile strength value of MDF powder-added PVC composites was found as 22.96 MPa for 10% MDF powder-added composite, while the lowest tensile strength value was determined for 20% MDF powder-added composite as being 19.9 MPa.

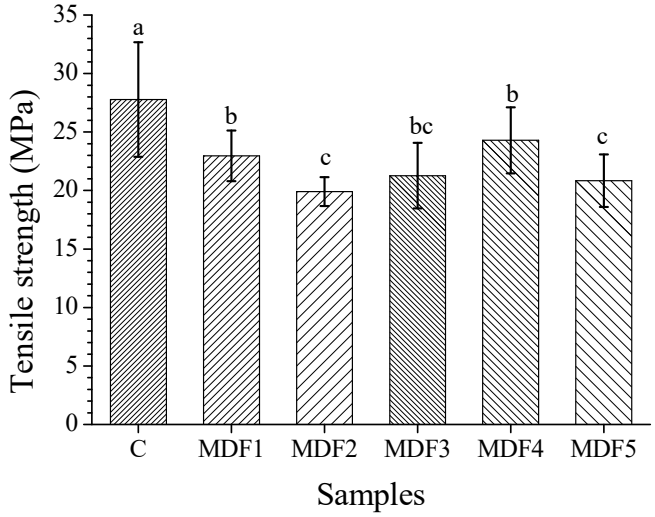

Figure 2. Tensile strength values of MDF powder-added PVC composites

In Figure 3, flexural strength values of wood flour-added PVC composites were given. As shown in the figure, it was determined that the flexural strength values of composites increased over 50 MPa with the addition of wood flour into PVC matrix up to 30%. However, it evidently decreased under 40 MPa with the addition of 40% and 50% wood flour. Flexural strength values of pure polymer and 10% and 20% wood flour added composites showed statistically similar values of 56.81, 56.26 and 54.4 MPa, respectively. On the other hand, composite samples with 40% and 50% wood flour have the lowest flexural strength values among all composites with a 38.13 MPa and 38.02 MPa flexural strength, respectively.

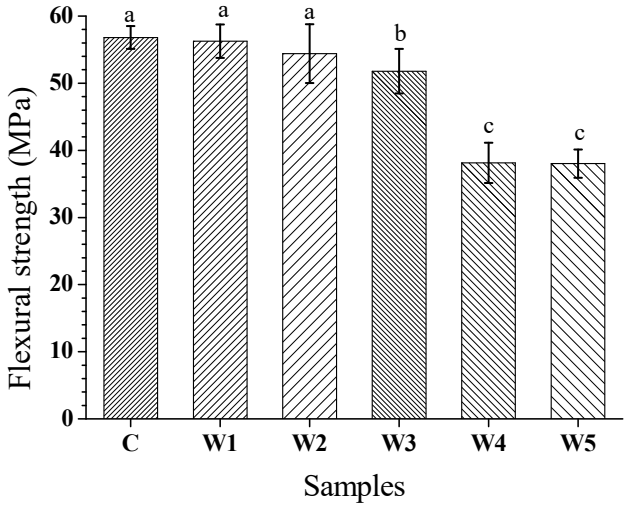

Figure 3. Flexural strength values of wood flour-added PVC composites

The flexural strength values of MDF powder-added PVC composites were given in Figure 4. As can be seen, the highest (62.59 MPa and 59.47 MPa) flexural strength values were obtained withthe addition of 10% and 50% MDF powder into the PVC matrix. On the other hand, by adding 20% MDF powder into the PVC matrix, the lowest (49.94 MPa) flexural strength value was obtained. The 30% and 40% MDF powder-added composite specimens showed statistically similar flexural strength values of 54.36 MPa and 53.49 MPa, respectively.

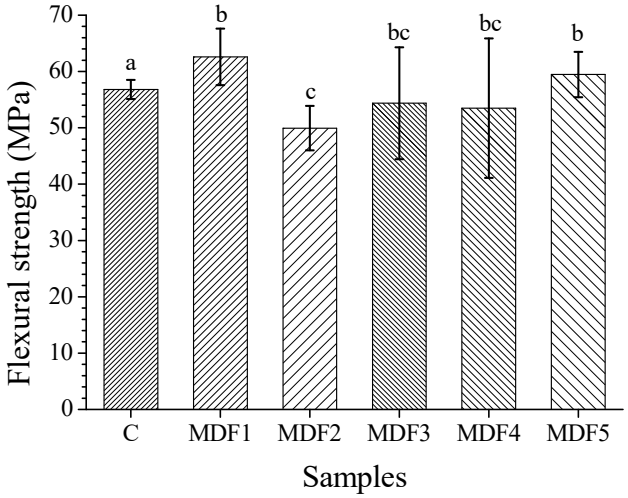

Figure 4. Flexural strength values of wood MDF powder-added PVC composites

Chaharsoughi et al. (2018) produced wood plastic composites containing PVC and 10, 15, and 20% sanding dust of medium density fiberboard as a wood-based panel waste. They determined that the flexural strength of the composites considerably decreased with the 10% MDF sanding dust. They also reported that increase in MDF dust content from 10 to 20% did not change the flexural strength of the composites.

In Figure 5, the impact strength values of wood flour added PVC composites were given. As shown in the figure, impact strength values of composites were decreased with the addition of wood flour into the PVC matrix. The impact strength values of 10-20-30% wood flour added composites showed statistical similarity. The highest impact strength value of composites was found as 20.88 J/m for 30% wood flour added composite sample. On the other hand, the lowest impact strength value was determined as 17.31 J/m for PVC composite with 50% wood flour filler.

Iulianelli et al., (2010) were tested the impact strength of PVC/wood flour composites. They found that the impact strength of the composites changed substantially at low wood content. They also reported that impact strength of composite sample with 10% of wood flour reduced approximately 60%, while samples produced with 25 and 40% of wood flour showed a similar result with approximately 75% decrease in impact strength.

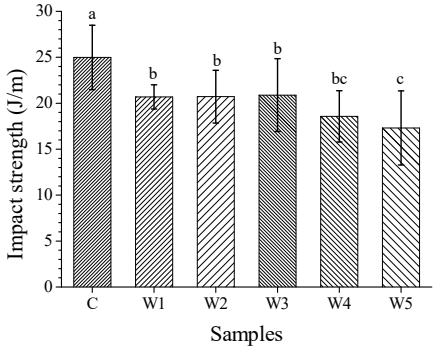

Figure 5. Impact strength values of wood flour-added PVC composites

Impact strength values of MDF powder-added PVC composites were given in Figure 6. As can be seen, the impact strength values of the composites gradually decreased with the increasing ratio of the MDF powder in the composite mixture. Among MDF powder added composites, the highest impact strength (23.6 J/m) was determined for 10% MDF powder added composite and the lowest impact strength value was found as 16.32 J/m for the composite containing 50% MDF powder. On the other hand, the impact strength values of 30% and 40% MDF powder added composite samples were statistically similar to each other with an impact strength value of 19.88 J/m and 19.36 J/m, respectively.

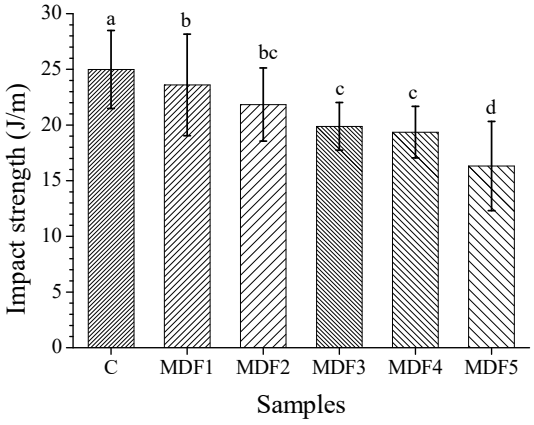

Figure 6. Impact strength values of MDF powder-added PVC composites

4 Conclusion

In this study, the evaluation of the furniture industry wastes in polymer composite production was investigated. Composite materials were obtained by adding 10% to 50% MDF powder waste and sawdust into PVC matrix. The results showed that:

- It was determined that the tensile, flexural and impact strength values of composites obtained by using wood flour gradually decreased with the increasing ratio of wood filler. On the other hand, the increase in the ratio of MDF powder caused a decrease in tensile and impact strength values in comparison with pure PVC polymer, and an increase in some flexural strength values.
- The tensile and flexural strength values of MDF powder-added PVC composites did not show a regular decrease with the addition of filler material. As a result, it was determined that the pine wood flour and MDF powder added PVC composites can be evaluated in structural applications requiring low mechanical properties such as wallboard, siding, door-window frame etc. Moreover, they can be used in various applications in the automotive sector as a plastic substitution.

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