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Preparation and characterization of wood plastic composite produced from waste polystyrene with organic filler

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Abstract – In this study, polystyrene (PS) polymer composites were prepared and characterized by mechanically and physically. It was aimed to produce a cheap, lightweight, and eco-friendly wood plastic composite (WPC). Waste PS was melted in a cap by gasoline, and 200 % wheat flour (PS(W)), wheat starch (PS(S)), and medium-density fiberboard (MDF) sawdust (PS(D)) were added into the melted PS. After the mixture was well mixed in a dough-like form, it was placed into wooden molds and molds were kept in the oven at 140 °C for 30 minutes and then taken out, and kept for 20 minutes at 4 °C. After the cooling process, the composites were removed from the molds and were cut to 18 mm x 15 mm x 40 mm dimensions using a diagonal saw. Mechanical characterizations were carried out by Internal bonding (IB), Screw holding resistance for edge (SRE) and surface (SRS), Pressure (PR). Physically characterizations were carried out by Density (DN), Water absorption (WA), Thickness swelling (TS). Results show that PS(D) has the highest mechanical properties despite its lowest density. PS(W) sample has better mechanical properties than PS(S) sample. It has been determined that the wood composite obtained by the combination of MDF waste dust with melted waste PS is close to the mechanical and physical properties of particleboard. Waste PS can be blended with wood dust and used on wood composite.

Keywords – Waste Polystyrene, Wood Plastic Composite, Polymer, Organic Filler, Wheat Flour, Starch

I. Introduction

Increasing human population has caused more consumption of wood raw material. For this reason, composite products have started to be developed as an alternative to massive wood material. One of the most important problems in composite products is formaldehyde emission [1]. For this reason, wood plastic composites (WPC) are important when the less emissions and wood were desired. WPC products have been used frequently in the furniture industry today [2].

Polystyrene (PS) is an important thermoplastic used in the manufacture of lightweight wood plastic composites. PS is one of the most widely used thermoplastic polymers in the world. Despite its low cost and excellent machinability, the need to improve the mechanical and physical properties of PS materials has emerged with the ever-evolving technology. In order to improve the properties of PS, nano inorganic fillers are blended with PS. In addition, PS/wood composites are frequently studied by researchers because of the economic advantage of using lignocellulosic fibers as fillers for thermoplastics [3]–[11]. Wood plastic composites (WPC) are quite competitive, thanks to their significant advantages such as low cost and the presence of natural fibers [11]–[15]. WPCs are made from a variety of materials, including plastics and natural fibers such as wood flour. They offer better features than solid wood and plastic composites and can be processed like plastic. However, creating WPC requires careful consideration of material compatibility and production processes, with challenges in optimizing formulation, processing variables, and composite stability [16].

Previous research suggests that the mechanical properties of WPCs can be improved through the hybridization effect of surface-treated mica and wood flour on polystyrene composites. The physical and mechanical properties of WPCs are influenced by factors such as wood species, particle size, and particle treatment. Additionally, the addition of wood flour to the matrix plastic improves the impact resistance of WPCs [17]–[19]. The use of lignocellulosic fibers in composites can have some drawbacks, such as degradation at low temperatures and low compatibility with the non-polar polymer matrix. The strong intermolecular hydrogen bonding between the fibers can cause agglomeration during the mixing process, leading to low interfacial adhesion and ultimately resulting in low mechanical and thermal properties of the final products [20–22].

In this study, heat was not used in the melting of PS. therefore these disadvantages do not exist. Waste PS was melted using gasoline and mixed with waste medium density fiberboard (MDF) flour (PS(D)), wheat flour (PS(W)) and starch (PS(S)). The aim of the study is to evaluate the waste PS and MDF flour, to bring them back into the economy and to help reduce environmental pollution.

II. Materials and Method

A. *Material*

Waste polystyrene (PS) was collected from garbage containers in the city. Colors of collected PSs were white, blue, and green and 10-20 kg/m^3 density. Wheat flour and wheat starch were purchased from the local market. Stach density, jell-time temperature and color were 1,5 gr/cm^3, 60-70 second, white respectively. Wheat density, jell-time temperature and color were 0,6 gr/cm^3, 80-85 second and light yellow respectively. The gasoline used to melt the polystyrene was purchased from a local oil office.

B. *Method*

In this study, samples were prepared by a different method from the conventional wood plastic composite production. In the conventional method, thermoplastics are melted using a heated extruder and mixed with fillers. However, in this method, the PS thermoplastic was melted with gasoline and the fillers were manually mixed into the PS. In addition, the prepared mixture was placed an oven and the gasoline was foamed as a foaming agent. In this way, the density of the composite is also reduced. For this purpose, 200 grams PS was melted in a plastic container using 100 grams of gasoline. PS in dough consistency was blended with MDF, wheat and starch flour in certain proportions (Table 1). The sample mixtures were prepared by hand kneading (Fig. 1a, 1b and 1c). Samples were molded and were kept in the oven at 140 degrees for 30 minutes. The samples taken from the oven were cooled at 4 degrees for 15 minutes. Samples were cut to 18 mm x 15 mm x 40 mm dimensions using a diagonal saw (Fig.1d and 1e). The gasoline in the samples turned into gas in the oven, causing the material to foam and decrease its density (Figure 1f). Prepared samples were characterized mechanically and physically. (Fig. 1g) according to related TSE standard. Pressure (PR), internal bond (IB), surface screw holding(SRS), Edge screw holding (SRE), thickness swelling (TS), water absorption (WA) and density (DN) were carried out according to TS 3968, TS EN 319, TS EN 320, TS EN 317 respectively.

Table 1. Sample ingredients

Samples	PS* (g)	GS** (ml)	W*** (g)	S**** (g)	M***** (g)	Temp. (°C)	Time (minute)
PS(W)	200	100	200	-	-	140	30
PS(S)	200	100	-	200	-	140	30
PS(D)	200	100	-	-	200	140	30

PS* : Polystyrene (20 kg/m^3) S****: Starch flour
GS**: Gasoline M*****: MDF flour
W***: Wheat flour

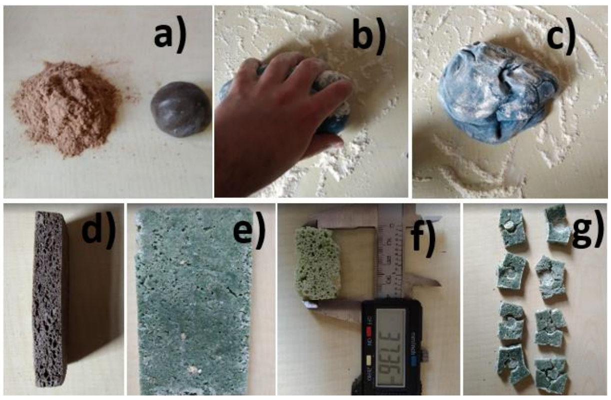

Fig. 1 Preparing the PS, wheat, starch, and MDF flour blended samples a) wood dust and melted PS, b) blending, c) blended PS and starch, d) PS(D) sample after oven, e) PS(W) sample after oven, f) PS(S) sample after oven, g) pressure analysis samples.

III. Results

When the Fig. 2 was examined, it was seen that the PS(W) and PS(D) strength was close to each other. However, considering that the density of

PS(D) is 32% less than that of PS(W), it can be said that the compressive strength of PS(D) is better. Similarly, the internal adhesion strength is high in the PS(D) sample, about 24-43% (Table 2).

Table 2. Mechanicals analyze results

Samples	Pressure (N/mm2) sig***: 0,01	Internal Bond (N/mm2) sig: 0,03	Surface Screw resistance (N/mm) sig: 0,01	Edge Screw resistance (N/mm) sig: 0,01
PS(W)	11,3 b** (±2,9)*	0,37 ab (±0,1)	38,9 b (±1,6)	28,5 b (±3,7)
PS(S)	4,7 a (±0,9)	0,32 a (±0,2)	28,2 a (±1,8)	22,4 a (±1,6)
PS(D)	10,4 b (±1,6)	0,46 b (±0,7)	51,7 c (±2,5)	45,4 c (±1,1)

*Standard deviation
**Letters symbolize the Duncan analyzes groups
***One-way Anova significant level

According to the screw holding analysis results, it was determined that PS(D) had the highest screw holding resistance. When the thickness swelling of the samples was examined, it was determined that the highest amount of swelling was in the PS(W) sample. Also, when the Table 3 was examined, It was seen that the least amount of swelling was PS(D).

Table 3. Physical analyze results

Samples	Thickness Swelling (%) sig***: 0,01	Water Absorption (%) sig: 0,01	Density (Kg/m^3) sig: 0,01
PS(W)	7,8 c (±1,3)*	30,4 b (±3,1)	570 c (±4,6)
PS(S)	6,6 b** (±0,3)	26,1 a (±1,7)	500 b (±3,7)
PS(D)	2,4 a (±0,4)	44,2 c (±2,0)	430 a (±9,1)

*Standard deviation
**Letters symbolize the Duncan analyzes groups
***One-way Anova significant level

Although the PS(D) sample had the lowest TS value, the amount of WA was found to be the highest. While the samples lost their moisture in the oven, they were also foamed by the gasification of the gasoline. Thus, it caused the densities of the samples to be different. The samples with the highest foaming and the lowest density are PS(D), PS(S) and PS(W), respectively.

IV. DISCUSSION

When the fig. 2 was examined, it was seen that the lowest mechanical properties was in PS(S) sample. It cannot be said that the low density caused this. because although the density of PS(D) sample is lower, it has the best mechanical properties. Here, it can be said that the binding property of starch in PS matrix is lower than that of wheat flour. It can be said that the addition of MDF flour, which consists of circular saw waste, into the PS matrix provides a better compatibility with PS compared to other samples.

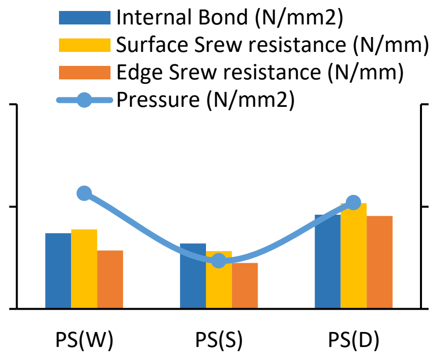

Fig. 2 Mechanical properties

When Figure 3 is examined, it was seen that although the lowest density was in PS(D), PS(D) had the best mechanical properties. Gasoline acted as a foaming agent in the matrix and foamed the polymer. The foaming rate was different because different mixtures prepared. Thus, the densities of the composites were different.

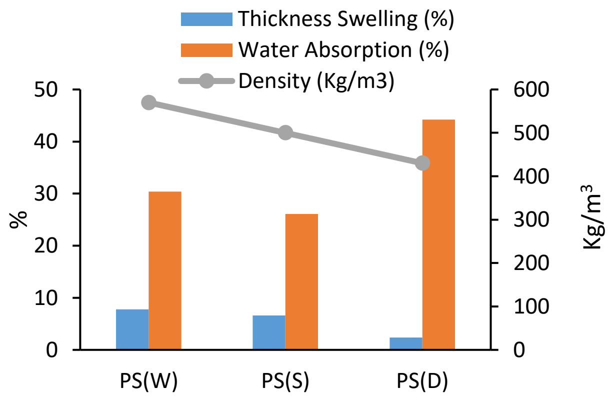

Fig. 3 Physical properties

When the Table 4 was examined, it can be seen the difference of the samples were significant (P<0,05) according to One-way Anova analysis.

Table 4. One-way Anova analysis results

Analysis		Sum of Squares	df	Mean Square	F	Sig.
PR	Between	177	2	88	21	,000
	Within Groups	75,9	18	4,2		
	Total	253	20			
IB	Between	,07	2	,03	4,5	,025
	Within Groups	,14	18	,008		
	Total	,21	20			
SRS	Between	494275	2	247137	241	,000
	Within Groups	18441	18	1024		
	Total	512716	20			
SRE	Between	510468	2	255234	167	,000
	Within Groups	27429	18	1523		
	Total	537897	20			
TS	Between	115	2	57,9	81,4	,000
	Within Groups	12,7	18	,71		
	Total	128	20			
WA	Between	1166	2	583	102	,000
	Within Groups	102	18	5,6		
	Total	1269	20			
DN	Between	68600	2	34300	865	,000
	Within Groups	713	18	39,6		
	Total	69313	20			

CONCLUSION

In this study, waste polystyrene was blended with waste MDF dust (flour), wheat flour and starch. As a result of the analysis, it was concluded that MDF saw waste is a good filler in PS polymer melted with gasoline. In addition, it was concluded that the use of wheat flour and starch as filler in PS reduces the mechanical properties of the composite. Polystyrene wastes can be mixed with wood chips obtained from the wastes of the forest products sector to help prevent environmental pollution.

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