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DETERMINATION OF SELECTED PROPERTIES OF PP BASED COMPOSITES FILLED EGGPLANT (*Solanum melongena*) STALKS

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Abstract:
Composite materials are produced by combining two or more different components to form an individual product with better properties. Manufactured new composite materials may provide better performance than one component can provide by itself. Wood-plastic composites are manufactured by using thermoplastics and annual plant waste. In this study, utilization of eggplant (solanum melongena) stalks as a filler in manufacturing of injection molded PP based composites was investigated. For this purpose, neat polypropylene test samples (control group) and eggplant stalks flour-filled thermoplastic composites with different rates (7.5% 15% and 30%) were produced by using single-screw extruder and injection molding machine. Maleic anhydride polypropylene (MAPP) was utilized as coupling agents. Paraffin wax was used as a lubricant. Mechanical properties (tensile strength, flexural strength and impact strength) of produced composites were determined according to ASTM D 638, ASTM D 790 and ASTM D 256 standards. According to the statistical analysis, eggplant stalk flours had significant effect on tensile strength, tensile modulus, flexural strength, flexural modulus, elongation at break properties and density values. However, it had no significant effect on the impact strength properties. All produced composites provided standards requirements.

Key words: *injection molded; eggplant (solanum melongena) stalks; wood-plastic composite.*

INTRODUCTION

The usage of lignocellulosic fibers as fillers in the manufacturing of thermoplastic-based composites is increasing day by day. Moreover, the production of thermoplastic composites is a rapidly growing sector in the wood-plastic composite industry. A large variety of lignocellulosic wastes (wood flour, agricultural wastes etc.) and thermoplastic polymers such as polylactic acid (PLA), polyethylene (PE), and polypropylene (PP) can be used in the manufacture of composites. The reasons for preference of lignocellulosic fibers in thermoplastic composite are low cost, low density, no excessive wear during production, high specific strength, abundant and easy degradation in the environment. These advantages make it attractive for the usage of lignocellulosic materials in the production of thermoplastic composites (Bodirlu et al. 2009; Taj et al. 2007; Antich et al. 2006; Khalid et al. 2006, Georgopoulos et al. 2005; Renneckar 2004; Nair et al. 2001). In the previous studies, it has reported that various lignocellulosic fibers such as maple and spruce wood fibers, jute, hemp, kenaf, sisal fibers, rice husks, wheat straw have been used in the production of thermoplastic composites (Poletto et al. 2011; Mengeloglu and Karakus 2008b; Mengeloğlu and Kabakcı 2008; Taj et al. 2007; Antich et al. 2006; Bengtsson and Oksman 2006; Digabel et al. 2004; Li and Matuana 2003). It has been determined that there is not enough study on the usage of eggplant stalks flour in the production of polypropylene based thermoplastic composite and there is a gap in that area.

With 18 million tons of eggplant production, China is the world leader. Turkey is in 4th place with 790 thousand tons of production. This amount accounts for 2% of world eggplant production. 30,000 hectares of eggplants are produced in Turkey (Topçu and Boyacı 2008). Eggplant is an annual plant species, dried plant stalks are collected and plant seedling is repeated in certain periods every year.

It is reported that 56 million tons of agricultural wastes are occurred in Turkey. (Karayılmazlar et al. 2011). These agricultural wastes are generally burned in the field and cause environmental pollution and reduce soil fertility (Çöpür 2007). It is thought that these wastes can be utilized as a filler in the composite manufacturing. It is aimed to prevent environmental pollution and contribute to waste management.

OBJECTIVE

The main objective of this study was to determine how waste eggplant (solanum melongena) stalks have effect on mechanical properties of PP based composites. For this purpose, polypropylene based thermoplastic composites reinforced with waste eggplant stalk flour were produced. The mechanical properties of the manufactured composites were determined and results were compared with the ASTM D 6622 standard.

EXPERIMENTAL

In this study, polypropylene based thermoplastic composites reinforced with waste eggplant stalk flour were manufactured by injection molding method.

Material

Waste eggplant stalks were obtained from farmers in the Mediterranean region of Turkey. Waste eggplant stalk flours were used as lignocellulosic filler. Polypropylene (PP) which obtained from PETKİM was used as thermoplastic matrix. Maleic anhydrite grafted polypropylene ((MAPP) Licomont AR 504 by Clariant) were utilized as coupling agents. Descriptions of coupling agents were given in Table 1. Paraffin wax (K.130.1000) was used as a lubricant.

Table 1

Descriptions of the coupling agent used in this study

Descriptions	**Licomont AR 504 (MAPP)**
Appearance	Yellowish fine grain
Softening point	156°C
Acid value	41 mg KOH/g
Density at 23°C	0.91 g/cm^3
Viscosity at 140 °C	800 mPa.s

Method

Preparation of lignocellulosic filler material

Eggplant stalks obtained from the farmers in the Mediterranean region were granulated into flour form with Wiley Mill. Since the dimensions of the filler materials have important effects on the performance of the produced compsoites, the lignocellulosic flours screened and retained on 60 mesh-size screen (0.25mm) and 100 mesh-size screen (0.142mm), were used in this study. The classified fillers were dried in oven at 103°C (±2) for 24 hours. It is important to use lignocellulosic fillers as a dried material in the manufacturing of polymer-based composites.

Manufacturing of polymer composites

The experimental design of the study was presented Table 2. Depending on the formulation PP, eggplant stalk flours (ESF), MAPP and paraffin wax were dry-mixed in a high-intensity mixer (900-1000 rounds per minute) to produce a homogeneous blend. These blends were compounded in a single-screw extruder at 40rpm screw speed in the temperatures (barrel to die) of 170-175-180-185-190°C. Extruded samples were cooled in water pool and then granulated into pellets. The pellets were dried in oven at 103°C (±2) for 24 hours (until moisture content reached approximately 0%). Dried pellets were injection moulded with 102kg/cm^2 injection pressure and 80mm/s injection speed to produce the test samples. The temperature used for injection moulded samples using an HDX-88 injection moulding machine was 180-200°C from feed zone to die zone. After manufacturing, all tests samples were conditioned in a climatic room with the temperature of 20°C and the relative humidity of 65%.

Table 2

Manufacturing schedule of composites (%)

Group ID	Polypropylene (%)	Eggplant Stalk flours (ESF) (%)	MAPP (%)	Wax (%)
E1	100	0	0	0
E2	87.5	7.5	3	2
E3	80	15	3	2
E4	65	30	3	2

Testing of polymer composites

Testing of the samples was conducted in a climate-controlled testing laboratory. Densities were measured by a water displacement technique according to the ASTM D 792 standard. Tensile, flexural, impact strengths, were determined according to ASTM D 638 (5.0mm/min), ASTM D 790 (2.0mm/min) and ASTM D 256, respectively. Ten samples for each group were tested. Flexural and tensile testing were performed on Zwick 10KN while a HIT5,5P by Zwick™ was used for impact property testing on notched samples. The notches were added using a Polytest notching cutter by RayRan™.

Data analysis

The data of produced samples were analyzed by using Design Expert® Version 7.0.3. statistical program. ANOVA test was used to determine the effects of the factors.

RESULTS AND DISCUSSION

PP based eggplant stalk flour (ESF) filled composites were produced in the density range of 0.88-1.00g/cm^3. The interaction graph of density was shown in Fig 1.

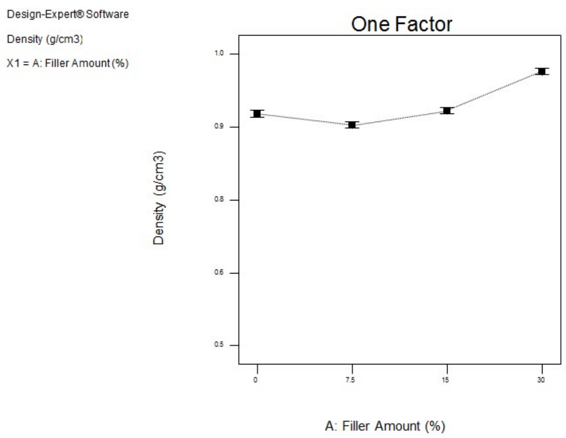

Fig. 1.
Interaction graphs of density.

When the interaction graph of density was examined, a slight increasing was observed in density values with the addition of ESF into the polymer matrix. However, this increasing wasn't statistically significant (P = 0.0918). In addition, the mechanical test results of the produced composite samples were summarized in Table 3.

Table 3

Mechanical properties of polymer composites

ID	Tensile Strength (MPa)	Tensile Modulus (MPa)	Elongation at Break (%)	Flexural Strength (MPa)	Flexural Modulus (MPa)	Impact Strength (J/m)
E1	27.82 (0.42)*	495.24 (19.73)	460	42.36 (0.96)	1129.48 (25.56)	16.91 (2.73)
E2	25.13 (0.34)	568.04 (17.46)	14.3 (0.87)	45.17 (0.49)	1202.62 (49.90)	17.84 (3.14)
E3	24.90 (0.30)	669.87 (23.66)	9.35 (0.41)	47.31 (0.58)	1751.82 (23.43)	20.61 (4.54)
E4	24.33 (0.45)	792.82 (29.04)	5.21 (0.28)	48.16 (1.19)	2253.10 (89.11)	16.05 (2.88)

* Values in parenthesis are standard deviations.

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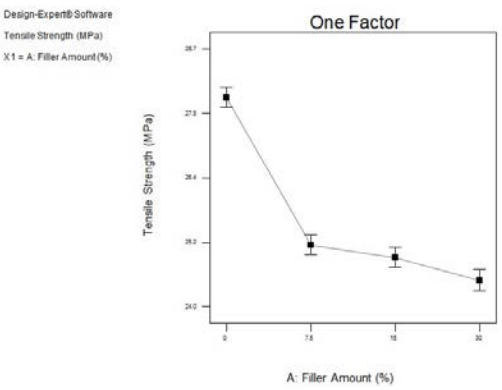
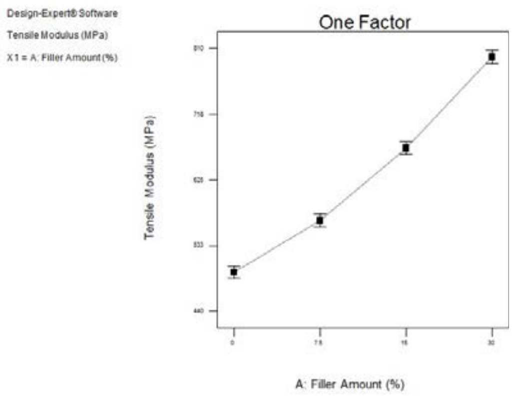
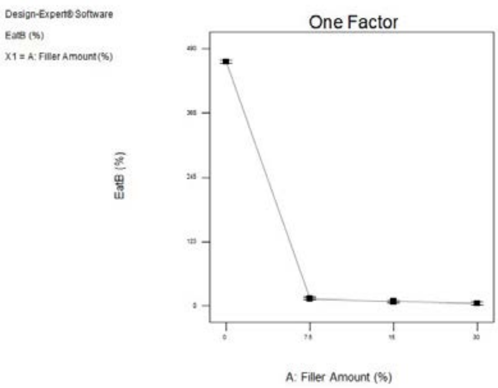
The interaction graphs of tensile, flexural and impact strength test samples were given in Fig. 2-4, respectively. The tensile properties included tensile strength, tensile modulus and elongation at break. The interaction graphs of tensile strength, tensile modulus and elongation at break were given in Figs. 2a, 2b and 2c, respectively.



(a)



(b)



(c)

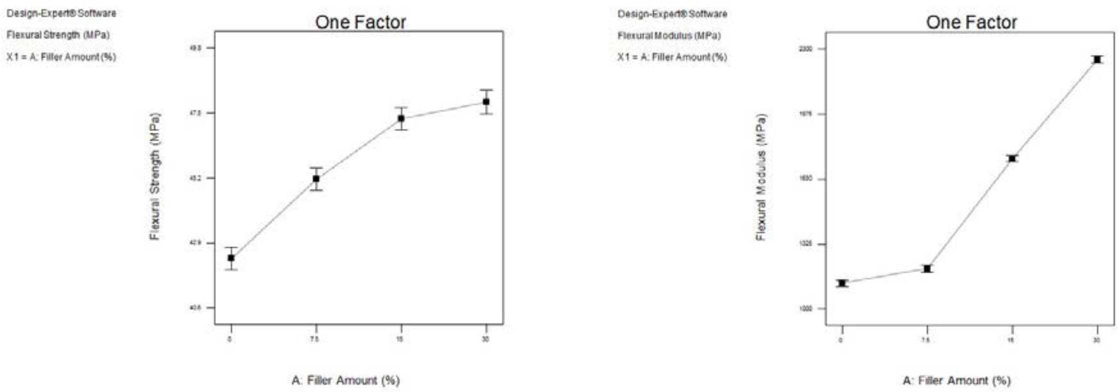
Fig. 2.
Interaction graphs of tensile properties:
a - tensile strength; b - tensile modulus; c - elongation at break.

ANOVA (analysis of variance) were performed for tensile properties results of manufactured composite samples. According to ANOVA test, Eggplant stalk flours (ESF) rate had statistically significant effect on tensile strength ($P<0.0001$). Tensile strength was significantly reduced with addition of ESF. It is thought that the most important reason of decline is lack of harmony between polymer matrix and lignocellulosic fillers (Balatinecz ve Woodhams 1993; Matuana ve Mengeloglu 2002).

To mention of tensile modulus, rise of ESF loading significantly increased the tensile modulus for composites ($P<0.0001$). Similar results for other wood flours filled polymer composites were also reported (Averous et al. 2000; Wang et al. 2003; Qiu et al. 2004; Mengeloglu et al. 2007). Lignocellulosic fillers have higher modulus than polymers. This is one of the advantages of the lignocellulosic fillers compare to polymer. That advantage leads to have higher modulus for wood plastic composites than unfilled polymer (Mengeloglu and Karakus 2008a). This can be explained by the rule of mixture (Matuana and Balatinecz 1998; Mengeloglu and Karakus 2008a).

ESF had statistically significant effect on elongation at break values ($P<0.0001$). With the addition of ESF, a decreasing in elongation at break was observed. Addition of the eggplant stalk flour into the PP polymer matrix, made the composites harder and more brittle. That was the reason why elongation at break values was reduced.

The flexural properties included flexural strength and flexural modulus. The interaction graphs of flexural strength and flexural modulus were shown in Figures 3a and 3b, respectively.



(a) (b)

Fig. 3.
Interaction graphs of flexural properties:
a - flexural strength; b - flexural modulus.

Eggplant stalk flours (ESF) rate had statistically significant effect on flexural strength ($P<0.0001$). An increasing was determined in flexural strength with the loading of ESF. To mention on flexural modulus, a significant increase was observed like tensile modulus ($P<0.0001$). Eggplant stalks have a higher modulus values than plastic materials (Hornsby et al. 1997). For this reason, when added to the polymer matrix, it increased the modulus values.

Results of the manufactured thermoplastic composites are compared with ASTM D 6662 (2001) standards. This standard is a standard for determining what the flexural strength values of polyolefin-based plastic lumber decking boards should be. Standard requirements are minimum 6.9MPa for flexural strength and 340MPa for flexural modulus. In this study, flexural strength values of the manufactured composites were found between 44.53-49.71MPa. All the produced composites were reached standard requirements. To mention on flexural modulus values, the results of the entire composite produced with ESF were determined between 1123-2453MPa. In parallel with flexural strength properties, all the produced composites were satisfied 340MPa which requested from ASTM D 6662 (2001) standard.

The interaction graph of impact strength was given in Fig. 4. According to these results, eggplant stalk flour ratio did not have statistically significant effect on impact strength ($P=0.0918$).

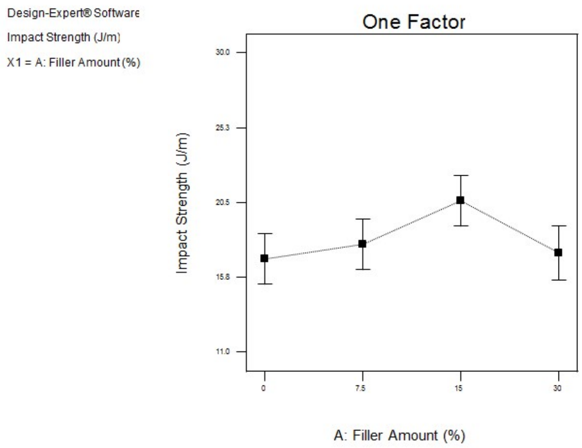


Fig. 4.
Interaction graphs of impact strength.

CONCLUSIONS

Polypropylene (PP) based polymer composites filled with different ratios of eggplant stalk flour were successfully manufactured by injection molding method. Density and mechanical results of manufactured composites were determined. According to results the following conclusions were reached;

- ✓ The eggplant stalk flour was significantly effective on the tensile strength and elongation at break properties of polypropylene based thermoplastic composites, with the increase of ESF rate in the composite, these properties were decreased.

- ✓ In contrast to tensile strength and elongation at break, with the addition of ESF, flexural strength, flexural modulus and tensile modulus values were improved. This increase was statistically significant.
- ✓ A decline was determined on the impact strength with the rise of ESF rate into the composites. However, this decrease was not statistically significant.
- ✓ All produced composites in this study provided flexural strength and flexural modulus values well over required ASTM D 6662 (2001) standards.

As a result, eggplant stalk flours were utilized as filler in the manufacturing of PP based composites. The utilization of these wastes in the production of thermoplastic composite materials might provide a new source of income for farmers. In addition, it might help to prevent from environmental pollution and reduce in soil fertility caused by burning of this kind of annual agricultural waste in the field.

REFERENCES

Anonymous (2000) Standard Test Methods for Impact Resistance of Plastics and Electrical Insulating Materials, ASTM D 256, Annual Book of American Society for Testing and Materials (ASTM) Standards, Philadelphia.

Anonymous (2001) Standard Test Method for Tensile Properties of Plastics. ASTM D 638, Annual Book of American Society for Testing and Materials (ASTM) Standards, Philadelphia.

Anonymous (2003) Standard Test Methods for Flexural Propertiesof Unreinforced and Reinforced Plastics and Electrical Insulating Materials, ASTM D 790, Annual Book of American Society for Testing and Materials (ASTM) Standards, Philadelphia.

Anticha P, Vazquez A, Mondragon I, Bernal C (2006) Mechanical behavior of high impact polystyrene reinforced with short sisal fibers, Composites: Part A 37:139–150.

Averous L, Moro L, Dole P, Fringant C (2000) Properties of Thermoplastic Blends: Starch- Polycaprolactone. Polymer 41:4157-4167.

Balatinecz JJ, Woodhams RT (1993) Wood-Plastic Composites, Doing More with Less, Journal of Forestry 91(11):22-26.

Bengtsson M, Oksman K (2006) Silane crosslinked wood plastic composites: Processing and properties. Compos. Sci. Technol., 66:2177–2186.

Bodirlau R, Spiridin I, Teaca CA (2009) Influence of components ratio upon Mechanical Properties of Wood/Thermoplastic Polymer Composites, Cellulose Chem. Technol., 43(4-6):205-209.

Çöpür Y, Güler C, Akgül M, Taşçıoğlu C (2007) Some chemical properties of hazelnut husk and its suitability for particleboard production, Building and Environment, 42:2568–2572.

Digabel FL, Boquillon N, Dole P, Monties B, Averous L (2004) Properties of thermoplastic composites based on wheat-straw lignocellulosic fillers, Journal of Applied Polymer Science, 93:428–436.

Georgopoulos ST, Tarantili PA, Avgerinos E, Andreopoulos AG, Koukios EG (2005) Thermoplastic polymers reinforced with fibrous agricultural residues, Polymer Degradation and Stability 90:303-312.

Hornsby PR, Hinrichsen E, Trivedi K (1997) Preparation and Properties of Polypropylene Composites Reinforced with Wheat and Flax Straw Fibers, Part 1., Fiber Characterization, J. Mater. Sci., 32:443–449.

Karayılmazlar S, Saraçoğlu N, Çabuk Y, Ve Kurt R (2011) Bartın Orman Fakültesi Dergisi, 13(19):63-75.

Khalid M, Ali S, Abdullah LC, Ratnam CT, Choong SYT (2006) Effect of MAPP as coupling agent on the mechanical properties of palm fiber empty fruit bunch and cellulose polypropylene biocomposites, International Journal of Engineering and Technology, 3(1):79-84.

Li Q, Matuana LM (2003) Effectiveness of Maleated and Acryclic Acid-Functionalized Polyolefin Coupling Agents for HDPE-Wood Flour Composites, J. Thermoplast Compos., 16:551-564.

Matuana LM, Balatınecz JJ (1998) Effect of Surface properties on the Adhesion between PVC and Wood Veener Laminates, Polym. Eng. Sci., 38(5):765-773.

Matuana LM, Mengeloğlu F (2002) Manufacture of Rigid PVC/Wood-Flour Composite Foams Using Moisture in Wood as Foaming Agent, Journal of Vinyla and Additive Technology, 8(4):264–270.

Mengeloglu F, Kurt R, Gardner DJ, Oneil S (2007) “Mechanical Properties of Extruded High Density Polyethylene and polypropylene Wood Flour Decking Board” Iranian Polymer Journal. 16(7):477-487.

Mengeloğlu F, Karakus K (2008a) Some properties of eucalyptus wood flour filled recycled high density polyethylene polymer-composites, Turk J Agric For., 32, pp. 537-546.

Mengeloglu F, Karakus K (2008b) Thermal degradation, mechanical properties and morphology of wheat straw flour filled recycled thermoplastic, Sensors ISSN 1424-8220 8. pp. 497-516.

Mengeloglu F, Kabakci A (2008) Determination of Thermal Properties and Morphology of Eucalyptus Wood Residue Filled High Density Polyethylene Composites. Int. J. Mol. Sci., 9:107–119.

Nair KCM, Thomas S, Groeninckx G (2001) Thermal and dynamic mechanical analysis of polystyrene composites reinforced with short sisal fibres, Composites Science and Technology 61:2519–2529.

Poletto M, Dettenborn J, Zeni M, Zattera AJ (2011) Characterization of composites based on expanded polystyrene wastes and wood flour, Waste Management 31:779–784.

Qiu W, Endo T, Hirotsu T (2004) "Interfacial Interactions of A Novel Mechanochemical Composite of Cellulose with Maleated Polypropylene" J. Appl. Polym. Sci. 94:1326-1335.

Renneckar SH (2004) Modification of wood fiber with thermoplastics by reactive steam-explosion processing, Virginia Polytechnic Institute & State University, Doctor of Philosophy in Wood Science and Forest Products, Blacksburg, VA.

Taj S, Munawar MA, Khan S (2007) Natural fiber-reinforced polymer composites, Proc. Pakistan Acad. Sci. 44(2):129-144.

Topçu V, Boyacı HF (2008) Patlıcan Yetiştiriciliğinin Dünya ve Türkiye'deki Durumu. Tarımın Sesi, 20:18-21.

Wang Y, Yeh FC, Lai SM, Chan HC, Shen HF (2003) "Effectiveness of Functionalized Polyolefins As Compatibilizers for Polyethylene/Wood Flour Composites" Polym. Eng. Sci. 43(4):933-945.