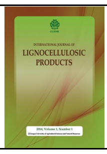

International Journal of
Lignocellulosic Products

2014, 1 (1): 50-57
http://ijlp.gau.ac.ir

GUASNR

Preliminary study of the physical and mechanical properties of soya stalk flour/high density polyethylene composite

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Received: 10 December 2012; Accepted: 16 January 2014.

Abstract

The use of agriculture residues as filler in composites is increasing due to their strength, abundance and low cost. Soya stalks show promising renewable natural fiber. In polyethylene composites the physical and mechanical properties (flexural resistance, tensile, impacted absorbed energy, water uptake and thickness swelling) was examined at different composites. The results showed that, the mechanical properties increased with soya stalk content However, the physical properties have tended to decrease.

Keywords**:** Mechanical properties, Natural fibers, Soya stalk flour.

1. Introduction

Traditional mineral fibers, glass, carbon, etc. have been expandly used as reinforcements in thermoplastics matrixes. These fibers incorporated into plastics with objective of reducing the costs and increasing of mechanical properties (Bledzki and Gassan, 1999; Yu et al., 2008). But nowadays, use of natural fibers such as wood fiber, wheat straw, cotton stalk, etc. due to low density, high specific strength, high resistance to crack propagation, abundant availability, low cost and non-toxic properties are growing (Esfandiari, 2007). Recent research in natural fibers such as wheat straw (Panthapulakkal et al., 2006), wood fibers (Ares et al., 210), corn stalk (Panthapulakkal et al., 2006), olive husk (Siracusa et al., 2002) and bamboo (Han et al., 2008) have shown that use of natural fibers as reinforcement to obtain well performance is possible.

The most interesting aspect use of natural fibers is the environmental friendly, renewable and biodegradable properties (Esfandiari, 2007). On the other hand, natural fibers represent some of the disadvantage such as high moisture uptake, low thermal stability, short fibers and no compatible behavior between polar natural fibers and non-polar plastics (Rowell et al., 1996). Nevertheless, some of these advantages can improve by chemical or other pretreatment.

Throughout the Iran, 311000 tons soya stalk is generated every year (Mehdinia and Tajvidi, 2011). Traditional use of these waste materials includes energy production, animal bedding, and etc. the burning of these waste material is another substitute way for remove of surplus amount of these unused materials; however the burning of agriculture residues is prohibited in many of countries, because of the environmental pollution (Panthapulakkal et al., 2006).

Use of these residues in composites manufacturing can open new view for these residues or by products and improve the rural agriculture based economy (Rowell et al., 1996; Panthapulakkal et al., 2006). In this study, we produced reinforced PE composite with soya stalk flour as the reinforcement, and then physical and mechanical properties of the composite were studied.

2. Materials and Methods

2.1. Materials

Soya stalks were obtained locally and were cut to short lengths, then chipped and milled (2-mm screen). The particles were screened to 40-60 mesh fractions and dried (moisture content 1%). The average fiber length and diameter was 1.16 mm and 35.8 μm, respectively. The soya flour had a composition of cellulose (49%), hemicellulose (18%), lignin (20.4%) and extractives (12.6%). Industrial polyethylene (Arak petrochemical company, Iran. MFI: 20 gr/10min, ρ: 0.956 g/cm^3) and maleic anhydrate polyethylene (MAPE) (Kimia Javid Sepahan Ltd. Co, MFI: 50-80 g/10 min, 0.8-1.2 maleic anhydrate) were mixed as received.

2.2. Methods

Table 1 shows the composition of the soya (40-60 mesh)/PE/MAPE mixed and dry blended.

Table 1. Summary of blend formulation of HDPE and soya stalk flour plus MAPE in HDPE/soya stalk flour composites.

	Variable factors		
Treatment code	Soya stalk flour (%)	Polyethylene (%)	Coupling agent (%)
1	40	58	2
2	40	56	4
3	50	58	2
4	50	56	4
5	60	38	2
6	60	36	4

The dry blend was compounded using a co-rotating twin screw extruder (USEON, TDS26B) at150- 160˚C and 190 rpm. The extrudate was cooled in water and granulated. The granules were injection molded into tensile, flexural and impact test samples. The used injection molding condition were: injection temperature: 180 ˚C; injection time: 10 s; cooling time: 4 s and injection pressure: 100 kg/m^2.

2.3. *Performance testing of composite*

Physical and mechanical properties of manufactured composite were performed according to ASTM Standards (with 3 replicate). The mechanical properties including impact absorbing energy (ASTM D-256), tensile (ASTM D-638) and flexural strength and modulus (ASTM D-790) were tested by an Instron testing machine (model 4486). The crosshead speed of 5 mm/min was performed for mechanical tests.

The physical tests including, water uptake and thickness swelling (ASTM D-570) after immersed water for 1440 h. In the first day, the weight and thickness of the samples was measured every 2 h. Then, in the second week the weight and thickness were measured daily. Finally, the weekly change in weight and thickness of the samples was measured until became constant.

3. Results and Discussion

3.1. *Mechanical properties*

Table 2 shows the average and standard deviation of mechanical properties of manufactured composite. The produced panels with 60% soya stalk exhibit higher tensile MOE and MOR than panels made with 40 and 50% soya stalk. With increasing soya stalk flour of 40% to 60%, the average tensile MOR and MOE values increase from 25.51 to 32.96 MPa and from 3092 to 5529 MPa, respectively. These differences were significance statistically in 95% confidence level.

Table 2. The average and standard deviation of mechanical properties of manufactured composite.

	40SSF+ 58PE+ 2MAPE	40SSF+ 56PE+ 4MAPE	50SSF+ 48PE+ 2MAPE	50SSF+ 46PE+ 4MAPE	60SSF+ 38PE+ 2MAPE	60SSF+ 36PE+ 4MAPE
Tensile Modulus (MPa)	3032 (90)	3153 (108)	3791 (232)	4549 (232)	4956 (225)	6102 (159)
Tensile Strength (MPa)	24.85 (0.277)	26.15 (0.424)	27.95 (0.906)	29.52 (0.650)	31.76 (01.925)	34.17 (02.18)
Flexural Modulus (MPa)	2113 (113)	2381 (35.5)	2690 (125)	3025 (60.5)	3641 (172)	3833 (155)
Flexural Strength (MPa)	40.73 (1.58)	42.48 (1.41)	44.32 (2.34)	45. 96 (1.66)	47.12 (1.73)	49.40 (2.41)
Unnotched Isod Impact (J/m)	50.19 (5.42)	50.85 (2.03)	46.25 (4.13)	48.88 (2.96)	26.90 (1.61)	29.52 (2.15)
Notched Izod Impact (J/m)	34.28 (2.44)	35.59 (2.01)	31.82 (3.7)	33.3 (3.11)	26.90 (1.61)	28.87 (3.21)

SSF: soya stalk flour, HDPE: high density polyethylene and MAPE: maleic anhydrate polyethylene
Data in parentheses are related to standard deviation.

The same trend was observed in flexural MOR and MOE values. The produced panels with 60% soya stalk exhibit higher mechanical properties than panels made with 40 and 50% soya stalk. With increasing soya stalk flour of 40% to 60%, the average flexural MOR and MOE values increase from 41.61 to 49.26 MPa and from 2247 to 3737 MPa, respectively. These differences were significance statistically in 95% confidence level.

This result is consistence with the general studies that, reinforcing the polymer matrix with lignocellulosic filler increases its tensile and flexural properties. Other researchers (Fuentes Talavera et al., 2007; Beg and Pickering, 2008; Chen et al., 2006, Kociszewski et al., 2010) indicated that the mechanical properties include, MOR and MOE of composite would increase with higher wood content. This effect was anticipated because more rigid particles (soya stalk flour) are agglutinated into the system.

In contrast to tensional and flexural MOR and MOE, impact absorbed energy values decreased with increase amount of soya stalk particles from 40 to 60%. Table 3 shows with increase of soya stalk particles from 40 to 60%, the average values of notched and unnotched impact resistance decreased from 49.95 to 39.53

J/m and 36.90 to 28.71 J/m, respectively. These differences were significance statistically in 95% confidence level.

As explained by other researchers, such as Panthapulakkal et al. (2006), owing to the essential role of lignocellulosic fiber and the lignocellulosic fiber– matrix interface, in short fiber composites, Impact fracture behavior is more complicated than virgin polymer. With addition of soya stalk flour in the HDPE matrix, the stress aggregation sites increase, the impact fracture mechanism will change and finally, the energy required for the initiation of crack will decrease.

Results in Table 3 shows influence of MAPE loading on the MOE and MOR of the WPC samples. It was clear that, tensile MOR and MOE were increased with MAPE increasing, and maximum increment was pertain to 4% MAPE usage.

Tensional and flexural MOR and MOE, Impact absorbed energy values increased with increase amount of MAPE percentage from 2 to 4% (Table 2). An increase of MAPE from 2 to 4%, the average values of notched and unnotched increased from 30.51 to 33.46 J/m and 44.29 to 47.24 J/m respectively. These differences were significance statistically in 95% confidence level.

This increment in mechanical properties was anticipated owing to the improving interaction between soya stalk flour and HDPE matrix in the composite and increasing stress transfer efficiency from the matrix to the fibers and leading to increasing in mechanical properties. Yang et al. (2007), Adhikary et al. (2008) and Ashori (2008, 2010) reported that, to improve the bonding strength between the lignocellulosic filler and the polymeric matrix, coupling agent is necessary. With addition of MAPP, mechanical properties of the composites significantly improved up to the pure matrix.

3.2. *Physical properties*

Table 3 shows the average and standard deviation of physical properties of manufactured composite. The produced panels with 40% soya stalk exhibit better physical properties than panels made with 60% soya stalk. The average water absorption and thickness swelling values increase from 6.76 to 10.93% and from 2.04 to 3.77%, respectively. These differences were significance statistically in 95% confidence level.

Table 3. The average and standard deviation of physical properties of manufactured composite.

	40 SSF+ 58PE+ 2MAPE	40SSF+ 56PE+ 4MAPE	50SSF+ 48PE+ 2MAPE	50SSF+ 46PE+ 4MAPE	60SSF+ 38PE+ 2MAPE	60SSF+ 36PE+ 4MAPE
Water absorption (%)	6.85 (0.205)	6.66 (0.360)	10.61 (0.383)	8.88 (0.181)	11.58 (0.110)	10.28 (0.274)
Thickness swelling (%)	2.065 (0.920)	2.023 (0.998)	3.382 (0.8267)	2.596 (01.04)	3.611 (1.176)	3.928 (1.146)

SSF: soya stalk flour, HDPE: high density polyethylene, MAPE: maleic anhydrate polyethylene
Data in parentheses are related to standard deviation.

The highest values corresponding to the panels with a high (60%) soya stalk flour content. With the higher soya stalk flour content, water absorption and thickness swelling rises. Because, soya stalk flour surface is inadequately protected by the plastic component, finally, the water uptake, and thickness swelling are increasing.

Result in Table 3, shows influence of MAPE percentage on the water uptake and thickness swelling of the WPC samples. It was clear that water uptake and thickness swelling were decreased with MAPE increasing, and maximum decrement was pertain to 4% MAPE usage. With increasing of MAPE content of 2 to 4%, water uptake and thickness swelling have been declined from 9.68 to 8.61% and 3.02 to 2.85%, respectively.

These results are agreement with other finding by other researchers (Bledzki 2005; Fuentes, Talavera et al., 2007; Shakeri and Omidvar, 2006). Expansion of linkages between functional groups of the coupling agent and hydroxyl groups on the soya stalk flour surface, avoids bonding of wood powder and water molecules, that restricts water absorption.

In addition, interactions of pair variables, the amount of soya stalk flour and MAPE content, significantly influence ($P > 0.05$) physical and mechanical properties of composites.

4. Conclusions

According to the test results, all mechanical properties of the panels, except impact absorbed energy property, were improved when the amount of soya stalk particles was increased from 40 to 60%. The best mechanical properties (includes flexural, tensile, notch and unnotched absorbed impact energy) were obtained when we used the 60/40 mixture ratio of soya stalk flour and HDPE, and 4% MAPE. But the best physical properties (includes water uptake and thickness swelling) related to 50/50 mixture ratio of HDPE and soya stalk flour, and 4%

MAPE. The results show that soya stalk can be used as reinforcement additives in thermoplastic composites.

Acknowledgment

We would like to thank Tehran University for financial help during this study.

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