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Determination of Optimized Condition for Soya Stalk Flour/Polyethylene Composite

[1]Meysam Mehdinia, [2]Ali Akbar Enayati and [2]Mohammad Layeghi

[1]Wood Composites of Agriculture Sciences and Natural Resources University of Gorgan, Iran
[2]Wood and Paper Science and Technology of Tehran University, Iran

Abstract: This study investigates optimized conditions for composite manufacturing using soya stalk flour and High Density Polyethylene (HDPE) matrix. The physical (water uptake and thickness swelling) and mechanical properties (Flexural, tensile and Impact absorbed energy) of the composite were studied. According to the test results, all mechanical properties of the panels (except impact absorbed energy property) were improved when the amount of soya stalk was increased from 50 to 60%. In addition, mechanical properties were increased with increase soya particles size and coupling agent (MAPE) content from 60-80 to 40-60 mesh and 2 to 4% respectively. However, Thickness swelling and water uptake values were increased when the amount of soya stalk particles and soya particle size increased from 50 to 60% and 60-80 to 40-60 mesh respectively. When the amount of coupling agent (MAPE) were decreased from 4 to 2%, Thickness swelling and water uptake values were increased. In summary, the results revealed that soya stalk could be used as reinforcement additives in thermoplastics conforming to the standards (ASTM standard).

Key words: Soya stalk · Natural fibers · Mechanical properties · Physical properties

INTRODUCTION

Wood or lignocellulosic fiber/polyolefins are the new generation of composites. The demand for these composites with a growing rate increased in recent decade [1]. Because of this, many reports about new technologies, material and method for improving properties of these composites were published annually [2,3].

Current uses of these composites are decking, windows profiles and furniture, fencing, dock and doorframes and automobiles panels [3]. These composites consisted of two phases. A continuous phase of polymer, like Polyethylene (PE), polypropylene on the one hand and a dispersed phase of filler, such as wood fiber or agriculture fibers on the other hand [4].

Recently use of agriculture residues as dispersed phase due to low density, high specific strength, abundance and low cost are increasing dramatically [5]. In addition, the forests with a high rate are decreasing, that use of agriculture residue fibers open new opportunities to replace the wood fibers by agriculture fibers [6]. One of the most abundant of these agro-fiber resources is soybean with a worldwide annual production of 261578498 Tons in 2011 [7]. Traditionally, soya stalk has been used as animal feeding, animal bedding or has been burned.

Many studies have been done on the use of agriculture fibers as reinforcement in thermoplastics. Reis *et al*. [6] reported that use of cork and rice husk ash micro particles as reinforcement into polyester increase glass transition temperature, the elastic modulus and also absorbed impact energy compared with polyester, but decrease flexural strength and fracture toughness. Best improvements were obtained, when using rice husk ash powder reaching about 30%.

Obi reddy *et al*. [8] investigated the suitability of coconut tree leaf sheath fibers as reinforcement by FTIR spectra analysis, chemical, X ray and thermo gravimetric methods. The chemical and FTIR analysis indicated lowering hemicelluloses content by alkali treatment of the fibers. The X ray diffraction revealed an increase in crystallinity of the fibers on alkali treatment and thermo gravimetric analysis indicated that thermal stability of fiber increase by alkali treatment. The mechanical and physical properties indicated that those fibers were suitable as reinforcement. As another approach, Han *et al*. [3] fabricated composites by use of HDPE, Nanoclay and

Corresponding Author: Meysam Mehdinia, Wood Composites of Agriculture Sciences and Natural Resources University of Gorgan, Iran.

bamboo as filler. They reported that tensile strength, bending modulus and tensile strength improved with use of MAPE. Mechanical properties reduced by use of clay in the system. Also they proposed techniques such as pre-coating fiber clay-MAPE mixture, to enhance the synergetic effect of the clay and bamboo fiber on the composite properties.

In the present work, we fabricate the soya stalk flour/HDPE composite with different mixing ratios of HDPE and soya stalk flour, maleic anhydrate grafted polyethylene (MAPE) and two particle size of soya stalk flour. Their mechanical and physical properties were also studied to determine the optimized condition in soya stalk flour/HDPE composite manufacturing.

MATERIALS AND METHODS

Materials: Soya stalks were provided by local farmers. The leaves and sheaths of the soya stalks were removed by hand and then were dried in air at 30°C to reduce moisture content to about 10-15%. The air-dried soya stalks were ground into small particles by use of *Pullman* flakers and were grounded by a Laboratory mill. Only particles that could pass through a sieve of mesh 20-40 µm and 40-60 µm were used in this study. The selected soya stalk particles were dried at 105°C for 24 hours to reduce moisture content to below 1%. The HDPE was obtained from Arak petrochemical company, Iran. The MAPE were also purchased from Kimia Javid Sepahan Ltd. Co. The combination used for manufacture of soya stalk flour/HDPE composite are shown in Table 1.

Table 1: The combination of various factors for manufacture of soy stalk flour/HDPE composite.

	Variable factors			
Treatment code	Particles size (mesh)	Soya stalk flour (%)	Polyethylene (%)	Coupling agent (%)
1	20-40	40	60	2
2	20-40	50	50	2
3	20-40	60	40	2
4	20-40	40	60	3
5	20-40	50	50	3
6	20-40	60	40	3
7	20-40	40	60	4
8	20-40	50	50	4
9	20-40	60	40	4
10	40-60	40	60	2
11	40-60	50	50	2
12	40-60	60	40	2
13	40-60	40	60	3
14	40-60	50	50	3
15	40-60	60	40	3
16	40-60	40	60	4
17	40-60	50	50	4
18	40-60	60	40	4

Methods

Sample Preparation: The dried soya stalk flour, HDPE and MAPE compounding, were done in a co-rotated extruder (at 150- 160°C and 190 rpm). The blends to obtain pellet were ground in a Labratory granulator. From the pellet, the flexural, tensile and impact energy samples were produced in an injection molding with injection temperature at 180 °C, injection pressure at 100 kg /m^2 and injection time at 10 S. The prepared samples were stored in acclimatized conditions (at temperature of 20±1 °C and relative humidity 65±2 %).

Performance Evaluation: The mechanical properties include of flexural and tensile were determined using of Instron testing machine accordance to ASTM D790 and ASTM D638 standards respectively. Also Impact test was determined by Santam machine accordance with ASTM D256 standard. The physical properties (water uptake and thickness swelling) were also carried out according to ASTM D570 standard.

ANOVA Analysi: The ANOVA and Duncan analysis were applied for statistical analysis in this research.

RESULTS AND DISCUSSION

Mechanical Properties

The Effect of Soya Stalk Flour Content: The mechanical measurements were done and the results are presented in Table 2. As it can be seen in the Fig. 1, that demonstrate the effect of adding soya stalk flour on the flexural MOE and MOR of panels, the composites with 60% soya stalk have highest values among other mixture ratios. Moreover, with increasing of soya stalk flour of 40 to 60 %, the average tensional MOE and MOR value decreased from 3092.66 to 5529.5 MPa and 25.51 to 32.96 MPa, respectively. These differences were found statistically significant at 95% confidence level.

The similar trend was found for flexural MOR and MOE values. As is illustrated in the Fig. 2, the panels have been made with 60% soya stalk exhibit higher mechanical properties than panels made with 40 and 50% soya stalk content. With increasing soya stalk flour of 40% to 60%. The average flexural MOR and MOE values increase from 42.9 to 46.25 MPa and from 2247.42 to 3737.42 MPa, respectively. These differences were found statistically significant at 95% confidence level.

Table 2: Average of mechanical properties of soy stalk flour/HDPE composite

Treatment code	Tensile Modulus (MPa)	Tensile Strength (MPa)	Flexural Modulus (MPa)	Flexural Strength (MPa)	Notched Isod Impact (J)	Unnotched Isod Impact (J)
1	3053 (83.328)	24.814 (0.28536)	2389.6 (124.595)	42.438 (1.77255)	0.468 (0.06017)	0.346 (0.02510)
2	3791.17 (232.781)	24.7533 (0.90686)	2690.33 (125.459)	41.7383 (2.34613)	0.4567 (0.03011)	0.3017 (0.03710)
3	4956.83 (266.213)	26.7617 (1.92539)	3641.17 (172.892)	43.0967 (1.73247)	0.5033 (0.04131)	0.29 (0.03033)
4	3627.50 (181.575)	26.2617 (0.65331)	2346.67 (109.250)	45.7917 (0.94326)	0.53 (0.02530)	0.403 (0.03933)
5	3539.33 (127.513)	25.6233 (1.30796)	2800.83 (73.257)	44.3633 (1.28974)	0.49 (0.02530)	0.3217 (0.02858)
6	4760.5 (149.717)	26.5883 (1.10884)	3606.33 (154.096)	44.6817 (2.27835)	0.5167 (0.04844)	0.313 (0.01633)
7	3153.33 (108.256)	26.2583 (0.42410)	2113.83 (35.572)	43.32 (1.41999)	0.543 (0.03266)	0.4083 (0.05382)
8	4549.33 (232.083)	27.5283 (0.65024)	3025.67 (60.513)	48.1233 (1.66371)	0.4967 (0.03011)	0.323 (0.04033)
9	6102.17 (159.89)	34.17 (2.18127)	3833.67 (155.594)	49.4017 (2.41727)	0.30 (0.02191)	0.293 (0.03266)
10	3613.40 (99.372)	25.462 (0.66672)	2349 (104.836)	43.198 (1.29026)	0.434 (0.04561)	0.314 (0.06309)
11	3811 (219.538)	25.895 (1.30394)	3114.17 (101.612)	43.8417 (2.09925)	0.4767 (0.03266)	0.2867 (0.03933)
12	6717.33 (209.184)	28.4217 (0.91596)	3814.33 (146.747)	42.5033 (1.76091)	0.4967 (0.03933)	0.243 (0.02338)
13	2995.17 (137.372)	24.9517 (0.80116)	2183.17 (88.017)	42.0067 (1.75481)	0.503 (0.04131)	0.3667 (0.04761)
14	3916.17 (303.811)	25.415 (1.28541)	2910.17 (235.527)	45.55 (3.19178)	0.47 (0.04195)	0.3483 (0.02483)
15	6096.67 (294.084)	27.3933 (1.38292)	3968.17 (138.209)	47.6683 (1.30136)	0.51 (0.05514)	0.273 (0.01633)
16	3241.17 (175.285)	26.24 (0.88139)	2286.17 (140.751)	45.6767 (1.35502)	0.543 (0.03266)	0.3967 (0.02066)
17	3918 (67.290)	27.3017 (1.43101)	2963.67 (130.502)	47.0567 (2.00521)	0.5167 (0.02066)	0.3383 (0.03764)
18	4976.83 (287.013)	28.938 (0.43120)	3636 (192.613)	47.795 (1.59129)	0.273 (0.01633)	0.3617 (0.02041)

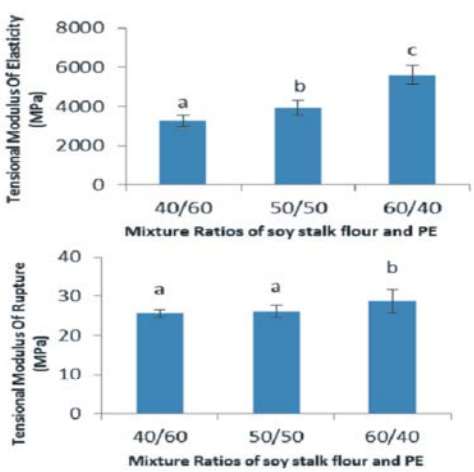

Fig. 1: The effect of mixture ratio on tensional MOR and MOE of panels.

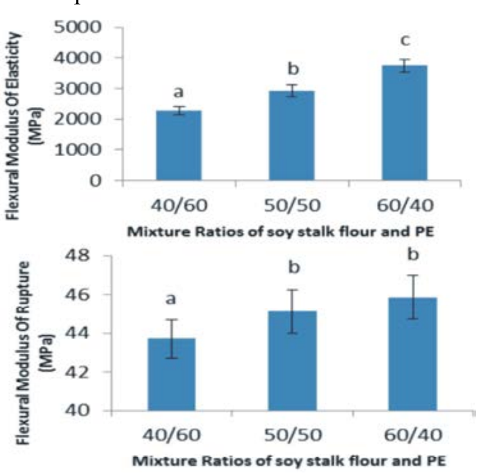

Fig. 2: The effect of mixture ratio on flexural MOR and MOE of panels.

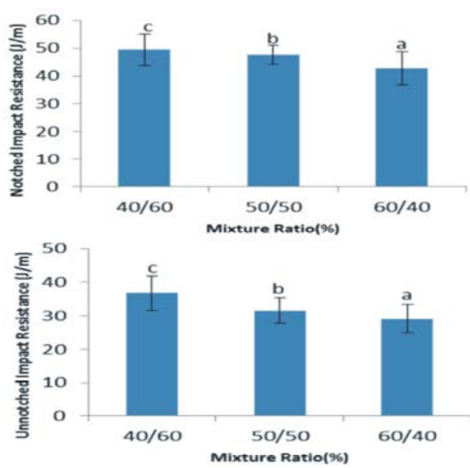

Fig. 3: The effect of mixture ratio on Impact absorbed energy of panels.

This result is in agreement with the general studies that, reinforcing the polymer matrix with lignocellulosic filler increases its tensile and flexural properties. In explanation of this effect could be said that, according to the increasing amount of lignocellulosic phase, the amount of available solid and stiff particles in the system is increased. So, the stress transfer from polymer to the filler phase is done well, leading to the composite breaks with higher energy [2,9].

As we have seen, with increasing soya stalk flour content, the flexural and tensional MOE and MOR were increased. However, in contrast to tensional and flexural MOR and MOE, Impact absorbed energy value decreased with increased amount of soya stalk particles from 40 to 60%. As Fig. 2 shows, with increase of soya stalk particles

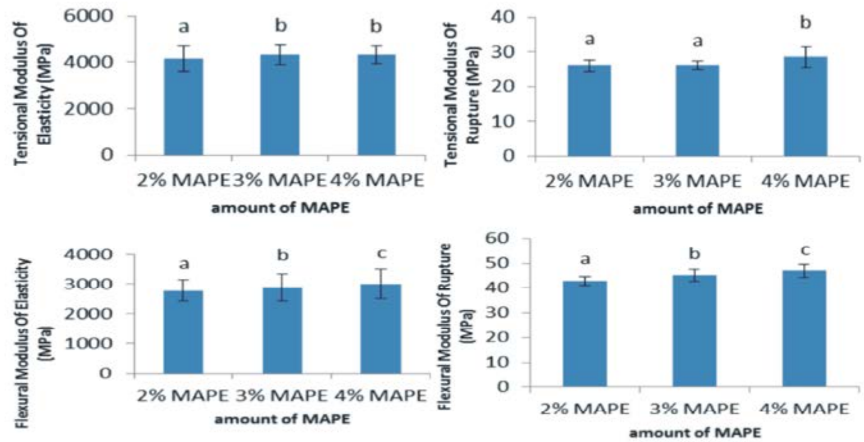

Fig. 4: The effect of amount of MAPE on Tensional and flexural MOE and MOR of panels.

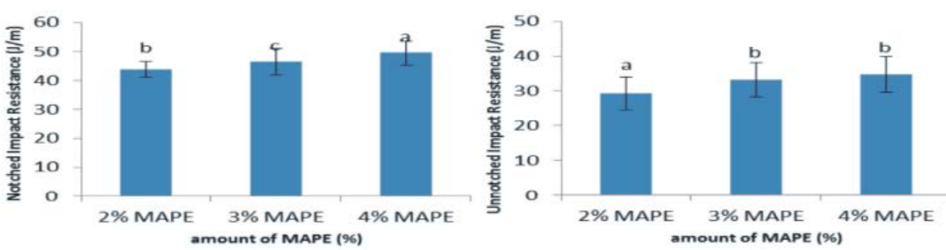

Fig. 5: The effect of amount of MAPE on Impact absorbed energy of panels.

from 40 to 60%, the average values of notched and unnotched impact resistance decreased from 0.51 to 0.40 J and 0.37 to 0.29 J, respectively. These differences were found statistically significant at 95% confidence level.

As explained by other researchers, such as [10], 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.

The Effect of MAPE Content: The influence of MAPE content on the MOE and MOR of the WPC panels has been shown in Fig. 4. There are significant differences between various content of MAPE on the tensional and flexural MOE and MOR. So that, with MAPE increasing, these properties increase and maximum increment were related to 4% MAPE usage.

Impact absorbed energy values, as well as flexural and tensional MOE and MOR, increased with increase MAPE content from 2 to 4%. According to Fig. 2, we can see that, with increase of MAPE from 2 to 4%, the average values of notched and unnotched increased from 0.45 to 0.48 J and 0.31 to 0.34 J respectively. These differences were found statistically significant at 95% confidence level.

This increment in mechanical properties shows the performance of the coupling agent (MAPE) in improving interaction between the soya stalk particles and the matrix phase and finally, ameliorating the stress transfer from polymer to the filler phase. Yang *et al*. [4] and Ashori *et al*. [12] 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.

The Effect of Particle Size (Mesh): Results pertaining to Fig. 6, the flexural and tensional properties of the composites increase significantly with larger size soya stalk particles. As we see, the tensional and flexural MOE and MOR values for particles with mesh 20-40 µm are 4365.44 and 26.98 MPa, respectively. However, these values for 40-60 µm decreased to 4168.02 and 26.63, respectively. These differences were found statistically significant at 95% confidence level.

Table 3: Average of physical properties of soy stalk flour/HDPE composite.

	1	2	3	4	5	6	7	8	9
Water uptake	6.67 (0.23)	6.88 (0.38)	4.58 (0.11)	6.81 (0.33)	4.57 (0.16)	5.04 (0.23)	7.86 (0.36)	10.62 (0.18)	8.28 (0.27)
Thickness swelling	2.02 (1.03)	2.59 (0.83)	2.31 (1.18)	2.91 (0.83)	2.32 (0.74)	2.56 (0.56)	3.06 (0.99)	4.38 (1.04)	3.338 (1.15)

Table 3: Continue

	10	11	12	13	14	15	16	17	18
Water uptake	9.94 (0.33)	7.67 (0.27)	9.74 (0.31)	10.34 (0.27)	13.12 (0.19)	11.55 (0.29)	10.72 (0.10)	12.43 (0.36)	13.78 (0.44)
Thickness swelling	5.03 (1.45)	3.34 (1.26)	4.3 (1.08)	5.99 (1.11)	6.8 (0.79)	5.7 (0.76)	6.36 (1.88)	6.45 (2.04)	6.69 (1.5)

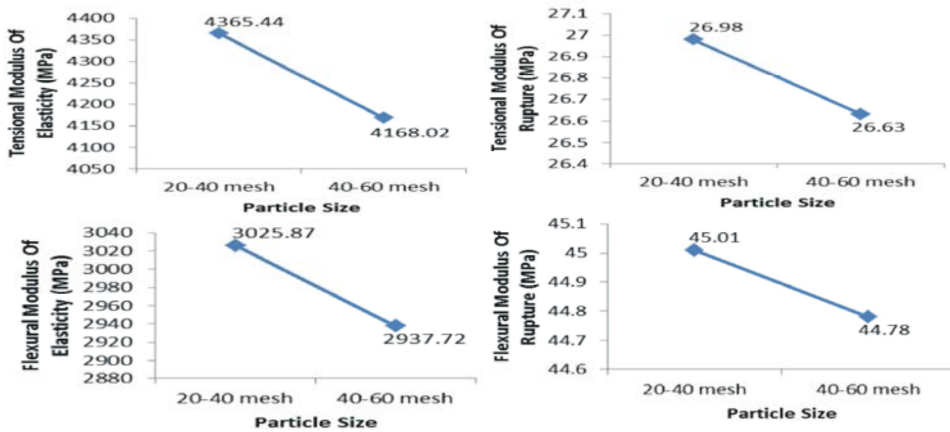

Fig. 6: The effect of particle size (mesh) on Tensional and flexural MOE and MOR of panels.

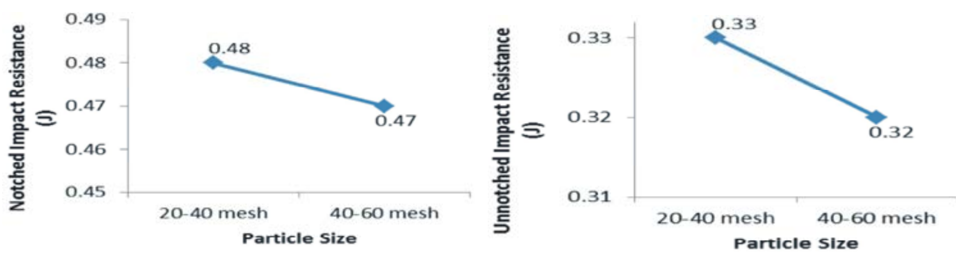

Fig. 7: The effect of particle size (mesh) on Impact absorbed energy of panels.

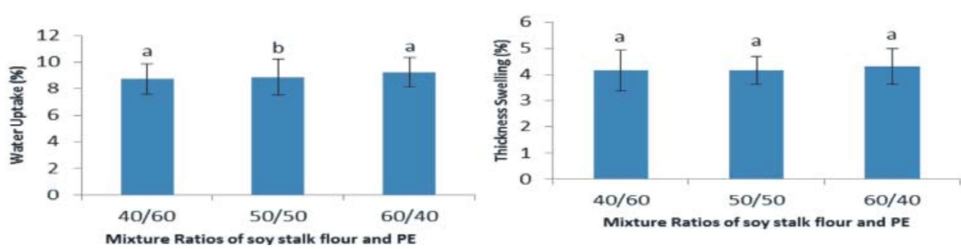

Fig. 8: The effect of mixture ratio on water uptake and water swelling of panels.

As MOR and MOE, impact absorbed energy values with decreasing soya stalk particles size, decreased. So that, the notched and unnotched impact energy for manufactured composites with 20-40 mesh soya stalk particle were 0.48 and 0.33 J, respectively and these values with decreasing soya stalk particles to 40-60 mesh decreased to 0.47 and 0.32, respectively.

One of the most important factor that affects mechanical properties of WPC is fiber length-to-thickness ratio that known as aspect ratio. In the produced samples with higher aspect ratio, these particles improve the WPC mechanical properties, compared with lower particle size [13]. In these samples, higher aspect ratios improve stress transfer from the matrix to the fibers and at last, improve the composite mechanical properties.

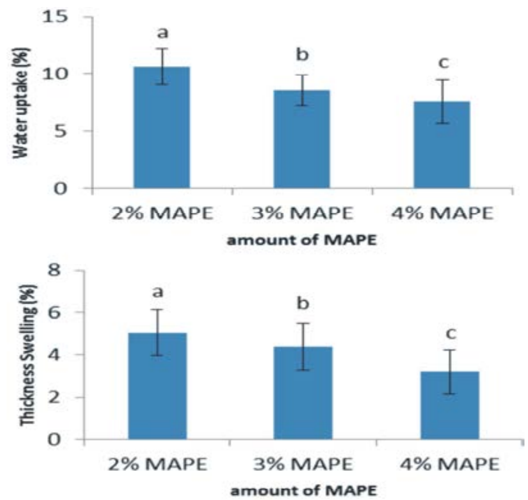

Fig. 9: The effect of amount of MAPE on water uptake and thickness swelling of panels.

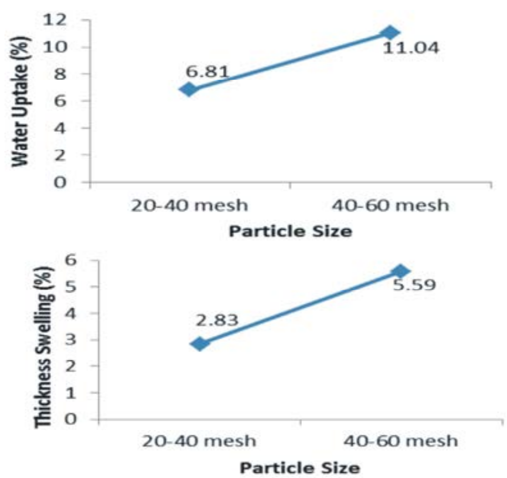

Fig. 10: The effect of particle size on water uptake and swelling of panels.

Physical Properties

The Effect of Soya Stalk Content: One of the interesting aspects of wood-plastic composite is dimensional stability. As shown in Table 3, the produced panels with 40% soya stalk exhibit better physical properties than panels made with 60% soya stalk. The water uptake and thickness swelling values of composite with increasing of soya stalk content of 40 to 60, increased from 6.67 to 13.78 and 2.04 to 3.77 respectively. These differences were found statistically significant at 95% confidence level.

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 and finally, the water uptake and thickness swelling are increasing.

The Effect of MAPE Content: As it can be seen in Fig. 9, with increasing of MAPE content the water uptake and thickness swelling had tend to decrease. In 2% usage of MAPE, average values of water uptake and thickness swelling were 10.62 and 5.04%, respectively. That with increasing MAPE content of 2 to 4% water uptake and thickness swelling values decreased to 7.58 and 3.2%, respectively. These results are strongly in agreement with findings obtained by other researchers [9,14,15]. 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.

The Effect of Particle Size (Mesh): In the thickness swelling and water uptake test, the composites made of 20-40 mesh size particles have greater thickness swelling and water uptake values than 40-60 mesh size particles. These differences were found statistically significant at 95% confidence level.

The composite made of smaller size particles had lower water uptake and thickness swelling compared with bigger size particles. With increasing in particle size, mixing efficiency decreases and soya stalk flour surface is inadequately protected by the plastic component and finally, the water uptake and thickness swelling are increasing.

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 was increased from 40 to 60%. In addition, mechanical properties were increased with increase soya particles size and coupling agent (MAPE) content from 40-60 to 20-40 mesh and 2 to 4% respectively. However, Thickness swelling and water uptake values were increased when the amount of soya stalk particles and soya particle size increased from 40 to 60% and 40-60 to 20-40 mesh respectively. When the amount of coupling agent (MAPE) were decreased from 4 to 2%, Thickness swelling and water uptake values were increased. 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, 20-40 mesh soya particle size and 4% MAPE. But the best physical properties (includes water uptake and thickness swelling) related to 40/60 mixture ratio of soya stalk flour and HDPE, 40-60 mesh soya particle size and 4% MAPE.

In summary, the results revealed that soya stalk could be used as reinforcement additives in thermoplastics conforming to the standards (ASTM standard).

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REFERENCES

1. Esfandiari, A., 2007. The statistical investigation of mechanical properties of PP/Natural fibers composites. Fibers & Polym. J., 9(1): 48-54.
2. Chen, H.C., T.Y. Chen and C.H. Hsu, 2005. Effects of Wood Particle Size and Mixing Ratios of HDPE on the Properties of the Composites. Holz als Roh-und Werkstoff. J., 64: 172-177.
3. Han, G., Y. Lei, Q. Wu, Y. Kojima and S. Suzuki, 2008. Bamboo-fiber filled High Density Polyethylene composites: Effect of coupling treatment and Nanoclay. Polym Environ. J., 16: 123-130.
4. Zena, S.N.G., L.C. Simon and A. Elkamel, 2009. Renewable agricultural fibers as reinforcing fillers in plastics: prediction of thermal properties. Thermal analysis and calorimetry. J., 96: 85-90.
5. Satyanarayana, K.G., K. Sukumaran, P.S. Mukharjee, C. Parithran and S.G.K. Pillai, 1990. Natural fiber-polymer composites. Cement & Concrete Composite. J., 12: 117-136.
6. Reis, P.N.B., J.A.M. Fereirra and P.A.A. Silva, 2011, mechanical behaviour of composites filled by agro-waste materials. Fibers and Polym. J., 12(2): 240-246.
7. Faostat. Fao. Org.,
8. Obi Reddy, K., G. Sivamohan Reddy, C. Uma maheswari, A. Varada Rajulu and K. Madhusudhana Rao, 2010. Structural characterization of coconut tree leaf sheath fiber reinforcement. Forestry Research. J., 21(1): 53-58.
9. Fuentes, F.J., J.A. Talavera, H.G. Silva Guzman, R. Richter Sanjuan Duenas and J. Ramos, Qquirarte. 2007. Effect of production variables on bending properties, water absorption and thickness swelling of bagasse/plastic composite boards. Indust crops and prod. J., 26: 1-7.
10. Panthapulakkal, S. and M. Sain, 2006. Injection molded wheat straw and corn stem filled Polypropylene composites. Polym Environ. J., 14: 265-272.
11. Yang, T.H., C.J. Lin, S.Y. Wang and M.J. Tsai, 2007. Characteristics of particleboard made from recycled wood-waste chips impregnated with phenol formaldehyde resin. Building and Environ. J., 42(1): 189-195.
12. Ashori, A., 2010. Hybrid Composites from Waste Materials. Polym Environ. J., 18: 65-70.
13. Kociszewski, M., C. Gozdecki, A. Nski, S. Zajchowski and J. Mirowski, 2010. Effect of industrial wood particle size on mechanical properties of wood polyvinyl chloride composites. Wood Prod. J., pp: 531-535.
14. Bledzki Andrzej, K. Wanyang, Zheng and Faruk Omar, 2005. Microfoaming of flax and wood fiber reinforced polypropylene composites. Holz als Roh-und Werkstoff. J., 63: 30-37.
15. Shakeri, A. and A. Omidvar, 2006. Investigation on the Effect of Type, Quantity and Size of Straw Particles on the Mechanical Properties of Crops Straw-High Density Polyethylene Composites. Polymer Scie and Technol. J., 19(4): 301-308.

00. Ares, A., R. Bouza, S.G. Pardo, M.J. Abad and L. barral, 2010. Rheological, mechanical and thermal behaviour of wood polymer composites based on recycled polypropylene. Polym Environ. J., 18: 318-325.

00. Panthapulakkal, S., A. Zereshkian and M. Sain, 2006. Preparation and characterization of wheat straw fibers for reinforcing application in injection molded thermoplastic composites. Bioresource Technol. J., 97: 265-272.