Synthesize and exploration of Almond shells – polyester particulate composites

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Abstract

The value addition of almond shells through composite material fabrication is considered in this experimental study. The almond micron sized powers eventually mixed with polyester resin at six different weight proportions. The compression moulding technique is used for fabrication of composites. For exploration the hardness testing, impact testing, Scanning Electron Microscopy (SEM), water absorption test and surface roughness tester were employed. The synthesizing, experimentations and findings were discussed in detail.

Keywords: *Composite, almond shell, compression moulding, SEM, Polyester resin*

1. Introduction

The composite material technology used to achieve the desired properties of material for fulfilling the application requirement or some other objectives like weight reduction, cost reduction etc. [1,2]. Even though the Almond shells (ASs) are major agricultural residues, they have low nutritional value for animals and also difficult for them for their digestion and resistance to decomposition in the ground, their use in polymer composites receives much attention. Green composite can be developed by 25 wt.-% of ASs and polylactide [3]. Eco friendly composites can be obtained by adding 30 wt% almond shell flour with butylene succinate [4]. The improvement in mechanical and rheological properties obtained by use of Almond Shells (ASs) particles in polypropylene matrix as reinforcement [5]. [6] added ASs particles at different rations with urea–formaldehyde (UF) resin to form Particleboards. flexural properties and internal bond strength are indirectly proportional to quality added of almond shell particles. The content of 30% in the mixture satisfies the mechanical properties. [7] used the Nut-shells of Argan (NA) particles with polypropylene and reported that the Young’s modulus improved with increase of particles content and decrease of particle size significant raise the Young’s modulus. [8] used the chemically treated ASs particles with Polypropylene (PP) and found that the Young's modulus improved 14% than untreated ASs particles, the ductility of composite improved in term of yield strain 31% than untreated ASs particles and also the increase of thermal stability was observed. [9] reported that the environmentally-friendly materials for food packaging composite can be obtained by ASs (10 wt%) with Poly(ε-caprolactone) matrix, The composites proved the improvement in mechanical properties, gain in elastic modulus of 17% at 10 wt% particle loading, Lower melting and crystallization enthalpies and higher crystallinity than neat Poly(ε-caprolactone) laminates. By increase of filler content the decrease in thermal stability, increase in oxygen and water vapour barrier properties.

2. Materials and methods

2.1 Composite matrix

The composite matrix design is: the almond shell is used as reinforcement material, the polyester resin is employed as matrix material, the accelerator was Methyl Ethyl Ketone Peroxide and the Cobalt octane as Catalyst.

2.2 Almond shell

The physical and chemical properties of Almond Shell are furnished in Table -1 and Table – 2 respectively. The reinforcement form of almond shell is shown in figure 1 and its average particle size 50 µm maintained throughout all the composites.

Table 1 Chemical properties of Almond Shell

Material	**Almond shell**
Moisture%	13
Ph	5.1
EC dS/m	0.8
N%DWt	0.5
P	0.3
K	0.4
Cl	0.07

Table 2 Chemical composition of Almond Shell

Particulate	Almond shell
Hemicellouse	59.9
Lignin	20.2
Ash	13.2
Others	6.5

Figure 1.The Almond Shell Powder

2.3 Polyester Resin

It is good binder, easy and excellent mold-ability, commercially available, low weight and compatibility with fibers. Hence the orthophthalic unsaturated polyester resin considered as matrix material. The mechanical properties of cured polyester resin are shown in Table 3.

Table 3 The properties of cured polyester resin

Property	Value
Density	1350kg/m3
Poisson's ratio	0.33
Young's modulus	1GPa
Thermal conductivity	0.21W/m0c

2.4 Methyl Ethyl Ketone Peroxide and cobalt octane

Methyl Ethyl Ketone Peroxide and cobalt octane are included as catalyst and accelerator respectively in the composite matrix.

3 Composite fabrication

The compression molding machine of 30 tone capacity is employed in Composite fabrication. Initially the almond shell particulates are mixed with polyester resin by the simple mechanical stirring and the mixture is poured into Molds in the Compression Mounding machine conforming to the requirements of various testing conditions and characterization standards. A stainless steel mold having dimensions of 300 × 300 × 3 mm3 is used for composite fabrication. The Figure 2 illustrate prepared die for making polymer composites. The Figure 3 is shown the composite preparation at the compression molding machine. The mould is compressed at a pressure of 2.6 MPa by upper jaw in the compression molding machine at temperature of 80°C and for two hours in the same condition in the machine. The weight % of the Almond Shell and Polyester Resin compositions varied six levels in the composite matrix (Refer Table 4). The samples prepared from each particulate reinforced polyester composites (Refer Figure 4).

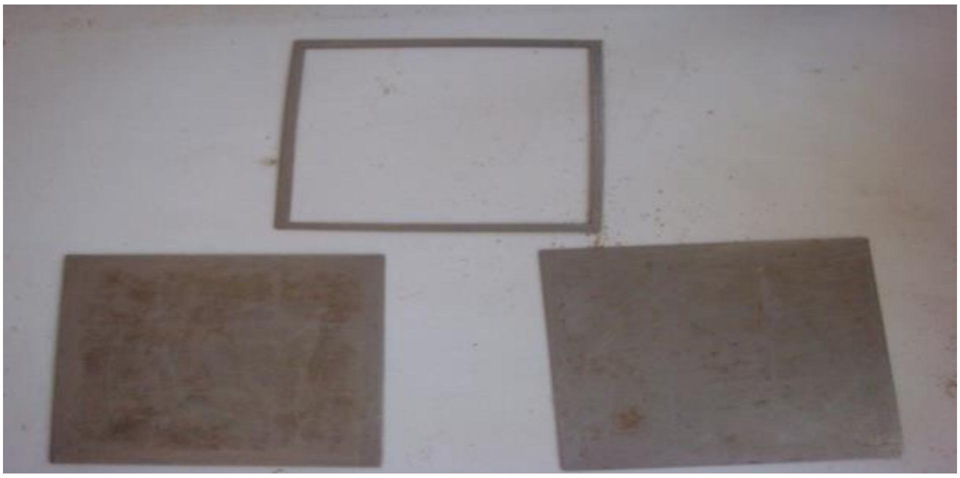

Figure 2.Fabricated Plate

Figure 3 Composite preparations at the Compression Molding Machine

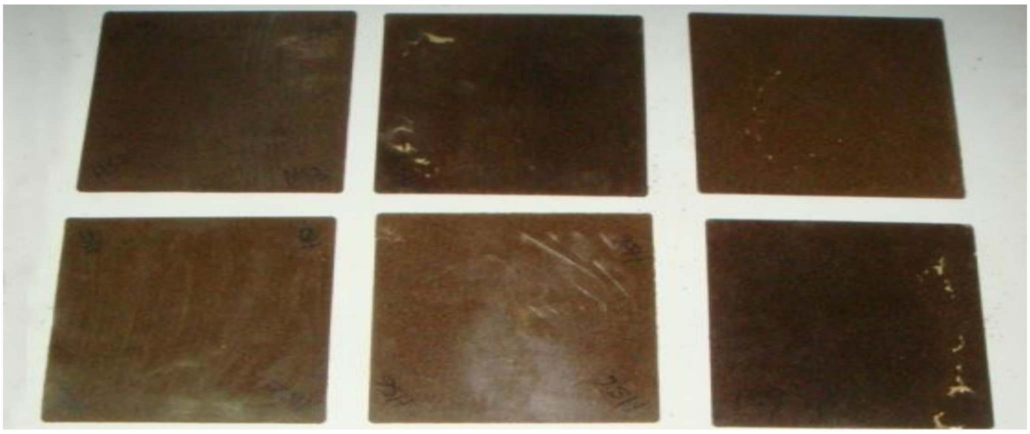

Figure 4 Particulates reinforced polyester composites

Table 4 Composition and Designation of the Almond- Polyester particulate Composites

Composite	C1	C2	C3	C4	C5	C6
Almond Shell Powder (Wt %)	5	10	15	20	25	30
Polyester Resin (Wt %)	95	90	85	80	75	70

4 Exploration on Composites

4.1 Investigation of Hardness of Composites

The standard model of Brinell hardness tester (Refer left end of Figure 5)) employed in this investigation. the ball of 1.5 mm diameter, the load of 5 kg were set in the machine. The sample size is three and the average value was recorded for computation. The observations are presented in Table 5.

4.2 Investigation of Impact Strength of Composites

The Tinius Olsen model Impact tester is employed in this investigation (Refer middle of Figure 5). The impact strength prepared composites are the toughness of them. Usually the Brittle materials have low toughness than ductile materials. the impact value is energy lost per unit cross-sectional area at J/m². the sample prepared as per ASTM D256. The dimensions of a standard specimen 64X12.7X3 mm. the toughness of the prepared particulate composites were investigated and presented in the Table 5.

Figure 5 Testing Equipment

4.3 Investigation of Surface Roughness of Composites

The surface texture plays an important role in many areas. In the failure mode effect analysis aspects the factor of surface roughness has great importance. Here the variation of surface roughness with respect to the work piece fiber orientation indicated that the surface roughness fluctuated for different fiber orientation. Mitutoyo SJ-310 model surface roughness tester (Refer right end of Figure 5) was employed in this investigation. The surface roughness of the prepared particulate composites were investigated and presented in the Table 5.

4.4 Investigation of Water absorption of Composites

The water absorption behavior of a composite depends on specific surface area, soak duration in water, polarity, the temperature of treatment and the temperature of treatment. The specimens of the Composites were taken as 75x25x3 mm3 rectangular thick plates. They weighed individually and recorded. They immersed in the water bath which contained distilled water for maximum 10 days or until the saturation was established. In between those samples are taken out at regular interval, wiped their surfaces with filter paper to remove the excess water from all sides, and then weighted them individually with an analytical balance ±0.1 mg resolution. The change of weight percentage was calculated for each sample at each interval and furnished them in the Table 6.

4.5 Surface morphological Investigation on Specific Composite

The Scanning electron microscopic images of fractures specimen considered for investigation. The fracture surfaces test study of almond shell filled polyester composite after the impact test has been shown in Figure 6. The SEM of impact failure surfaces of almond shell filled polyester composites with 5 wt. % of almond shell and 90 wt. % of polyester composites .The failure surfaces show feature of well-developed interfacial interaction. It can be seen there is very low pull-out of particle on the fracture surface in case of C1 composite. The surfaces of composites show that failure occurred at the particulate due to strong adhesion between dust and matrix. However, the failure surface of other composites (almond shell) show lesser impact strength, the impact fracture is more as compared with the other composites as shown. This may exhibit the weak interfacial adhesion between the almond shell and polyester matrix. The figure shown many holes left after the almond shell is pulled out from the matrix when the stress is applied and the failure occurred at the interface.

Table 5 Mechanical Properties of Particulate Composites

Particulate Composite	Hardness (BHN)	Impact strength (kJ/m2)	Surface Roughness Ra (μm)
C1	6	2.4	0.354
C2	8	3.1	0.724
C3	15	4.2	0.806
C4	9	4.5	1.593
C5	15.5	5.4	1.691
C6	7	6.1	1.088

Table 6 Water Absorption performance of Particulate Composites

Days / Composites	24	48	72	96	120	144	186	192	216	240
C1	12	15	16.5	19.5	23.5	25.5	28	30	32	33
C2	9.3	13.05	14.3	17.3	19.8	21.3	23.05	24.7	25.3	28.3
C3	8.07	10.07	12.07	14.07	16.07	17.57	19.07	19.57	20.32	20.82
C4	8.05	13.55	15.55	18.05	22.05	23.55	27.05	28.55	29.55	30.05
C5	8	14	15	18	20	23.5	25.5	27.25	28	29
C6	7.4	12.4	13.9	16.4	17.9	19.4	20.9	22.9	23.9	24.9

Figure 6. SEM Image of Impact tested C1 Composite

5 Results and discussion

The mechanical properties of the prepared almond shell are filled polyester composites and their water absorption characteristics were investigated. The results of various characterization tests are reported in the Table 5 and Table 6. This includes evaluation of Hardness, Impact strength, surface roughness, and water absorption test. The interpretation of the results and the comparison among various composite samples are also presented.

5.1 Hardness of the Almond shell filled polyester composites

The Hardness was conducted according to ASTM standard using Brinell hardness tester. The plot shows interaction between hardness and no of experiments. Hardness of polymer composites was performed in Brinell scale with a ball diameter of 1.5 mm and a load of 5 kg. It should be noted that the hardness results of the composites reported in this work are the average of three independent specimens.

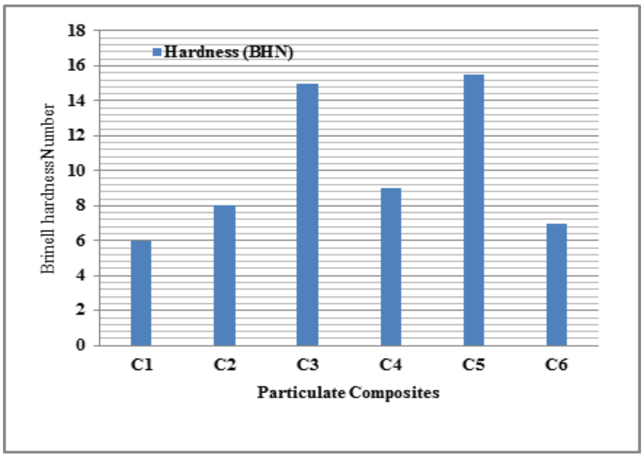

Figure 7. Hardness properties of particulate composites

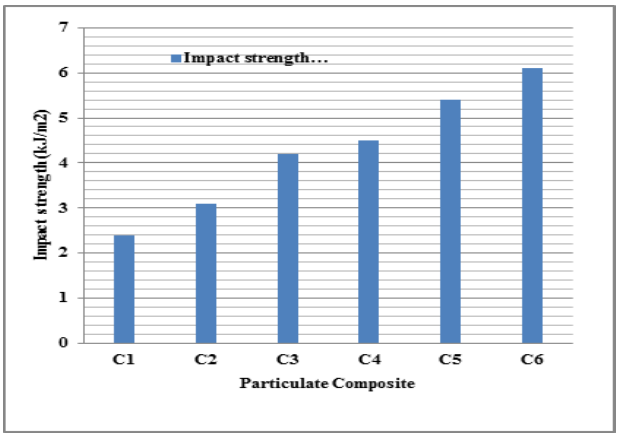

Figure 8. Toughness properties of particulate composites

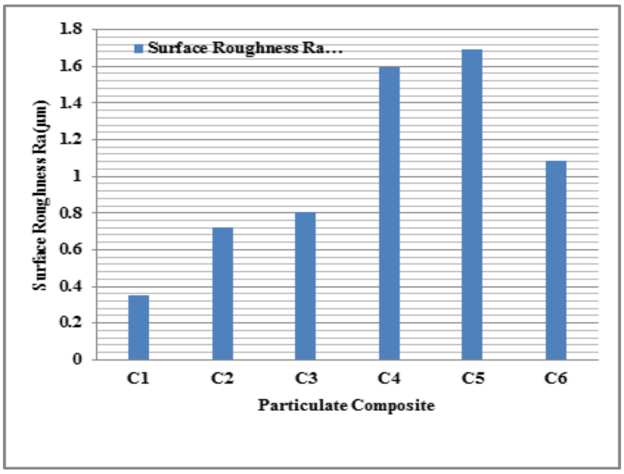

Figure 9. Roughness properties of particulate composites

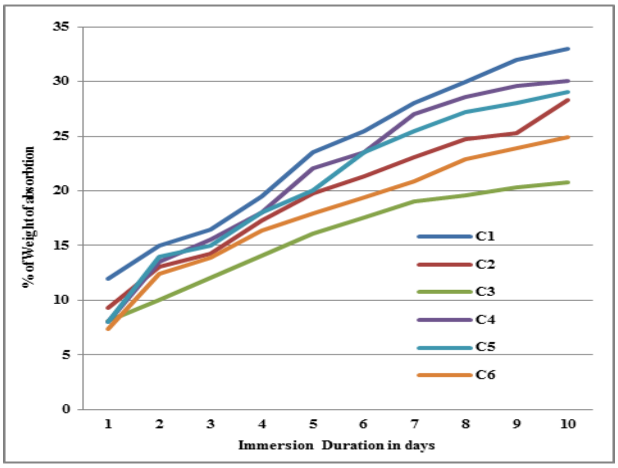

Figure 10 Water absorption of particulate composites

The Figure 7 shows the relation between hardness and no of experiments. The maximum hardness was 15.5 BHN with 25 wt % of almond shell and 70 wt. % of polyester. This is due to the more amount of cello use presence in the almond, moreover almond shell enchaining the strength of the composites. The least hardness was 6 BHN with 5 wt. of % almond shell and 90 wt. % of polyester. This Low is due to weak adhesions between the reinforced and matrix. Another important factor is low amount of reinforcement in the composites.

5.2 Impact strength of the Almond shell filled polyester composites

Figure 8 shows the relationship between the no of experiments and Impact strength in kJ/m2. The maximum structural property was obtained in all different compositions. The average impact strength of almond shell polymer composites is kJ/m2.

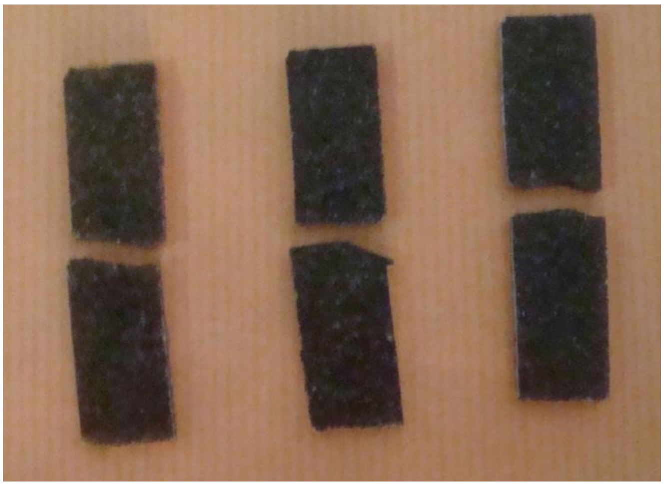

Figure 11 Almond shells filled polyester composite specimens after impact fracture

A low value of the impact strength of 2.1 kJ/m2 was obtained in S-1 composition that is 5 wt. % of almond shell and 90 wt. % of polyester composites. The maximum impact strength was 6.1 kJ/Sq. m attained with 30 wt. % of almond shell with 70 wt. % of polyester composites. This is due to resistance of almond shell, low amount of lignin and high amount of cello use presence in the almond shell.

5.3 Influence of the particulate content on surface roughness Ra (µm)

The variation of surface roughness with respect to the work piece particulate orientation indicated that the surface roughness fluctuated for orientation. The surface roughness increased more rapidly after 100 µm particulate orientations. The Figure.9.Influence of surface roughness on particulate composite. For evaluating condition cut off value of 0.8mm, cut off length 2.5 µm, while the more average surface roughness Ra is 0.354 µm when inculpating of coconut shell 5wt % of almond shell with 95 wt. % of polyester respectively. The maximum surface roughness Ra is 1.691 µm due improper adhesion between particulate and polyester matrix, generally polymer resin are amorphous structure in nature, because of this polyester surface will better, when incorporating with reinforcement particulate, surface of particle will improved due inability of resin.

5.4 Effect of Water absorption on almond shell particulate composites

The change in weight percent due to absorption of water by the composites for various time periods has been given below. Samples were exposed to moisture. The percentage of moisture absorption (%M)increased at the first day of absorption and gradually reached constant values. Percent weight change during moisture absorption was determined by the weight gain relative to the dry weight of the samples as follows:

$$M_{\%} = \frac{M_t - M_o}{M_o} \times 100\%$$

Where, M0 and Mt denote the dry weight of the sample and the weight at any specific time t, respectively. Equilibrium moisture absorption of samples was assumed to be reached when the daily weight gain of samples was less than 0.01%. Figure 4.4 shows the effects of particulate content on the moisture absorption behavior of the composite specimens. Moisture absorption increased with increase in the particulate content for all days. This is due to the enhancement of micro void formation in the matrix resin. Seventh, eighth and ninth day moisture absorption rate was nearly the same (Figure 4.4).Increasing particulate contents increased the moisture absorption. The hydrophilic character of natural particulates was responsible for the moisture absorption in the composites and therefore a higher content of particulates led to higher moisture absorption. When the particulate content increased, the saturation time shortened. The pores can act as stress concentration points, and can lead to premature failure of the composite during loading. Therefore, studies of the particulate surface topography could provide vital information on the level of interfacial adhesion that would exist between the particulate and the matrix later when used as reinforcement particulate at wet condition. Moisture absorption increased with increase in the particulate content. The high cellulose content in almond shell particulate further contributed to enhanced water penetrating into the interface through the micro cracks induced by swelling of particulates.

6 Conclusion and scope for further work

The mechanical behaviors of almond shell particulate were studied in this investigation. The particulate composites were fabricated as per the different combinations of the fabrication parameters. The composites were fabricated through 30 wt. % of particulate content and 95-70 wt. % of resin content and finished surface has examined through roughness value. The maximum hardness was 15.5 BHN with 25 wt. % of almond shell and 70 wt. % of polyester. . The maximum impact strength was 6.1 kJ/Sq. m attained with 30 wt. % of almond shell with 70 wt. % of polyester composites. The surface roughness of particulate composite was examined through surface roughness tester. The water absorption nature of polymer composites also analyzed. Natural particulates are biodegradable, easily available, and low cost and provide an opportunity for the development of natural material as reinforcement material. The performance tests of coir composite products are to be carried out to commercialize products. In this investigation flexural strength and wear behaviors have been extended to future project work.

7 References

[1] R. Saravanan, T. Gopalakrishnan and P. Jayakrishnamoorthy, 'Experimental Investigation of Influence of Sewing Type -Z Axis Reinforcement on Epoxy/Glass Fiber Composite', Journal of Advances in Mechanical Engineering and Science, (2016), Vol. 2(2), pp 20-30.

[2] R.Saravanan, P.Vivek and T.Vinod Kumar, 'Is Kevlar 29 / Epoxy Composite an Alternate for Drive Shaft? "Journal of Advances in Mechanical Engineering and Science. Vol.2(3), 2016, pp.1-13.

[3] L. Quiles-Carrillo, N. Montanes, D. Garcia-Garcia, A. Carbonell-Verdu and S. Torres-Giner, 'Effect of different compatibilizers on injection-molded green composite pieces based on polylactide filled with almond shell flour', Composites Part B: Engineering, Volume 147, 15 August 2018, Pages 76-85

[4] P. Liminana, D. Garcia-Sanoguera, L. Quiles-Carrillo, R. Balart and N. Montanes, 'Development and characterization of environmentally friendly composites from poly(butylene succinate) (PBS) and almond shell flour with different compatibilizers', Composites Part B: Engineering, Volume 144,1 July 2018, Pages 153-162.

[5] H.Essabir, S.Nekhlaoui, M.Malha, M.O.Bensalah, F.Z.Arrakhiz, A.Qaiss and R.Bouhfid, 'Bio-composites based on polypropylene reinforced with Almond Shells particles: Mechanical and thermal properties'Materials & Design, Volume 51, October 2013, Pages 225-230.

[6] .Hamidreza Pirayesh Abolghasem Khazaeian, 'Using almond (Prunus amygdalus L.) shell as a bio-waste resource in wood based composite, Composites Part B: Engineering, Volume 43, Issue 3, April 2012, Pages 1475-1479

[7] H.Essabir, E.Hilali, A.Elgharad, H.El Minor, A.Imad, A.Elamraoui and O.Al Gaoudi, 'Mechanical and thermal properties of bio-composites based on polypropylene reinforced with Nut-shells of Argan particles' Materials & Design, Volume 49, August 2013, Pages 442-448.

[8] Fatima Zahra El Mechtali, Hamid Essabir, Souad Nekhlaoui, Mohammed Ouadi Bensalah and Abou EIkacem Qaiss, Mechanical and Thermal Properties of Polypropylene Reinforced with Almond Shells Particles: Impact of Chemical Treatments, Journal of Bionic Engineering, Volume 12, Issue 3, July 2015, Pages 483-494

[9] ArantzazuValdés, GarcíaMarinaRamos, SantonjaAna BeltránSanahujaMaría and del Carmen GarrigósSelva, 'Characterization and degradation characteristics of poly(ε-caprolactone)-based composites reinforced with almond skin residues', Polymer Degradation and Stability, Volume 108, October 2014, Pages 269-279.