Influence of Extrusion Parameters and Coir on the Tensile Properties of HDPE

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ABSTRACT

Composites were prepared by extruding coir filled high density polyethylene in a tubular film extruder. Effect of coir as a reinforcing agent at various loading (0%, 1% and 2%) and extrusion parameters; screw speed (80, 100 and 120) rpm and barrel zone temperatures (150, 175, 175, 175, 190)°C, (150, 185, 185, 185, 200)°C and (150, 195, 195, 195, 210)°C on the tensile properties of high density polyethylene composite was studied. It was found that the tensile modulus increased with fibre content, while tensile strength, yield strength and elongation at break reduced with increase in fibre content. No distinct order was observed for screw speed and temperature changes. The reduction in the tensile properties of the composite as fibre content increased was due to increased pores. Hence as the pore size increased the tensile properties reduced.

1. Introduction

The search for engineering plastics having light weight, high strength and high fracture toughness has led to the development of a range of products known as reinforced plastics composites (7). The need for composite arose due to the need for engineering materials with high strength, high fracture toughness and light weight. This last property is advantageous in aerospace, transportation, sporting wares, chemical engineering e. t. c. The original engineering material like metals had these properties but their weights were comparably higher than those of polymer composites (2).

Polyethylene composite consists of two main components; the reinforcing element and the matrix. The reinforcements impact special mechanical and physical properties to enhance the matrix whereas the matrix surrounds and supports the reinforcement. However, because of the non-polar nature of polyethylene, it is important to coat the fibre with suitable coupling agents or adhesion promoters to achieve a strong bond between the fibre and polyethylene. Moreover, this will check interfacial separation during the service life of the plastic composites (7).

When long fibres are embedded on polyethylene, the composite has higher modulus and strength which are directional being very high in the fibre direction and very low in the transverse direction. However, short fibres have high strength and modulus but there is no directionality of properties. Also fibre reinforced polymers are corrosion resistant (7).

2. Materials and methods

2.1. Materials

The materials used in this study are:

- High density polyethylene (HDPE) and
- Coir

The polymer is produced by Indorama Group Eleme, Nigeria and it is film grade that was used. Some of the properties according to their technical data sheet are shown in Table 5.1

The coir was sourced locally. Some of its properties according to Canadian Society for Engineering in Agricultural, Food and Biological Systems data are shown in Table 5.2

2.2. Equipment

The following equipments were employed in this work:

1. Tubular or blown film extrusion machine produced by Hyun Sung Hydraulic Machine Company Limited Korea, model number HS792H
2. Adenturer electronic weighing balance manufactured by Ohaus Corporation China, Serial number 8726479733, item number AR3130
3. Tensile and elongation testing machine produced in Italy with serial number 112000 and model number HS-2
4. Calipers
5. Scissors
6. Stirrer
7. Electric stove
8. Thermometer
9. Micrometer screw gauge
10. Dumbbell shaped metallic mould
11. Syringe and
12. Manual press

2.3. Sample preparation

Coconut husks were sourced locally, washed with tap water and dried in FUTO erosion laboratory oven at about 70°C for ten hours. The husks were crushed and sieved with a mesh of 0.15mm diameter. The coir was washed with detergent (Omo) and warm tap water then soaked in hot water at 50°C and constantly heated to boil for 30 minutes. After which, the coir was soaked in a 5% sodium hydroxide (NaOH) solution for 30 minutes to activate the hydroxyl group to effectively react with benzoyl peroxide (BPO) in the succeeding treatment. Then distilled water was used to wash the coir. The coir was soaked for 30 minutes in a 60:40 ethanol/water mixture with benzoyl peroxide (BPO) as coupling agent. The amount of benzoyl peroxide (BPO) used was 3% by weight of fibre. Finally, the coir was washed with distilled water and dried on oven in FUTO erosion laboratory for twelve hours at about 70°C. Silicone oil was used as a processing aid. The formulation of the composite is shown in Table 5.3

The polymer (HDPE) and coir were weighed using; the electronic weighing balance, processing aid (silicone fluid) was added and mixed thoroughly in a mixer. The mixtures were then fed into the hopper of a blown film extruder produced by Hyun Sung Hydraulic Machine Company Limited Korea, model number HS792H.

This mixture was conveyed through the three basic zones of the extruder screw; feed, compression or transition and metering. The feed zone has a constant channel depth; thus the materials are conveyed via this zone and get heated. In the compression zone, channel depth decrease gradually resulting in material being compacted, heated by the heater-bands (thermocouples) and mechanically worked by the screw. The metering zone homogenizes and brings the melt via the breaker plate (filter) to where the melt is extruded vertically upwards via the annular die into a thin walled tube which is then inflated with air into a balloon or bubble. The breaker plate filters out heterogeneous materials in the mixture. The bubble is cooled by both the internal and external air line, collapsed between guides and nips rollers at the top and hauled off. The thickness or gage of the film depends on the die gap width, the draw-down ratio and the degree of inflation or blow-up ratio.

3. Procedure for data collection and analysis

The extrusion temperature (T), fibre content (F) and screw speed (S) for mixture of coir and HDPE are as depicted in Table 5.4

3.1. Tensile property test

The above named test was conducted with a tensile and elongation testing machine at a temperature of 23 ± 2°C, the maximum load cell capacity of the machine is 50 KN and it belongs to Socotherm Nigeria Limited, Onne, Rivers State. The actual load cell attached to the machine during the test was 2KN. The dumbbell shapes were cut using a metallic dumbbell mould and the thickness was measured with a calipers. These specimens were clamped on the machine and the test done on them according to ASTM D638.

The properties that were got from this test includes:-

- Tensile strength
- Yield strength
- Elongation at break and
- Tensile modulus

4. Results and discussions

4.1. Results

4.1.1. Tensile test results and calculations

The tensile test results are shown in table 5.5 and the values of the parameters that would be needed and definitions are given

L_o = 37mm = original length of the specimen

L_u = varied = final length of the specimen

Engineering stress (□) = Force / original cross sectional area

$= F_M / A$

Percentage elongation = (change in length/original length) 100

$= (\text{extension} / \text{original length})\ 100 = \{(L_u - L_o) / L_o\}\ 100$

The above table shows that the coir-filled HDPE showed low tensile and elongation character. Unfilled specimens were better in respect to their tensile and elongation property. However, coir-filled samples have better tensile modulus. The incorporation of the coir into the HDPE reduced the ductility of the composite hence the reduction noticed in the tensile and elongation character.

4.2. DISCUSSION

The specific cause of initiation of the neck is not always known for example, if the specimen cross section is differentially lower at a particular location but the sample is homogeneous otherwise, necking occurs there. If free volume is slightly higher or if the material has some in-homogeneity in the region, necking occurs. Or, if the local yield stress of the material is low at a specific location, the yield point is reached there before it is reached elsewhere (10).

Consequently, the production of the composite by tubular film extrusion presented films with varying thickness hence the difference in the cross section might be responsible for the low tensile strength, low yield strength and low elongation at break that resulted. Again, there might be some in-homogeneity in the composite resulting from poor compatibility between the filler and the high density polyethylene which resulted in this poor tensile strength, yield strength and elongation at break. Besides, the low tensile properties might be due to the presence of water in the composite.

However, the barrel zone temperature and screw speed did not show any remarkable influence on the outcome of the test result.

5. Conclusion

The result showed that tensile modulus increased by 97% with 2% fibre content which is remarkable however the other tensile properties decreased. Moreover, the temperature and screw speed variation did not show any noticeable effect.

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Appendix I

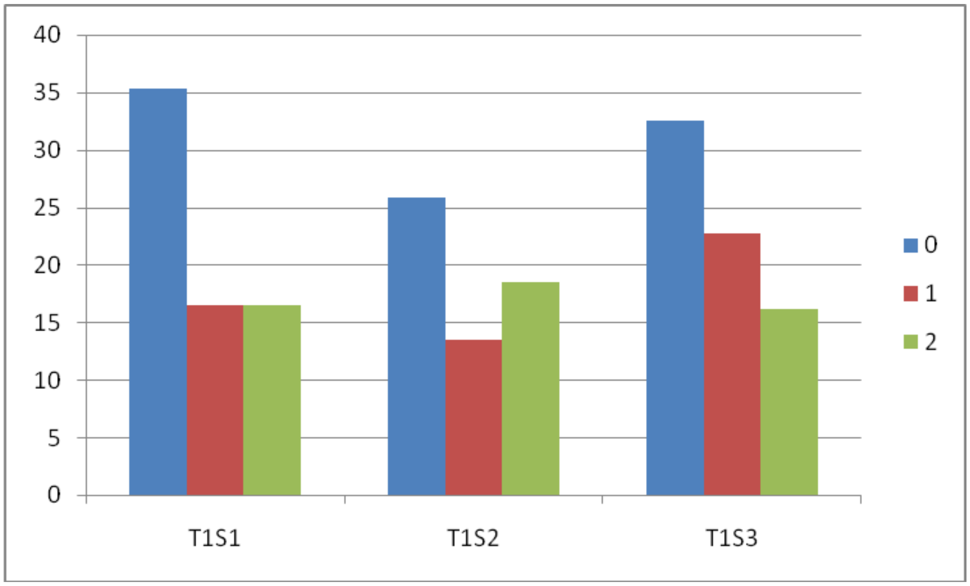

Figure 1. Tensile strength (N/mm^2) values at constant temperature (T_1), varying screw speed and varying filler content.

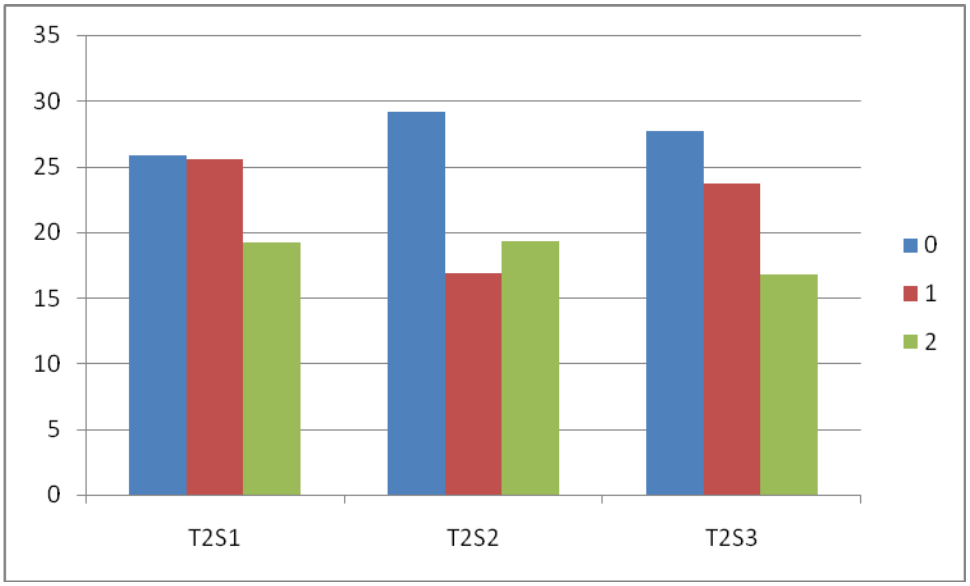

Figure 2. Tensile strength (N/mm^2) values at constant temperature (T_2), varying screw speed and varying filler content.

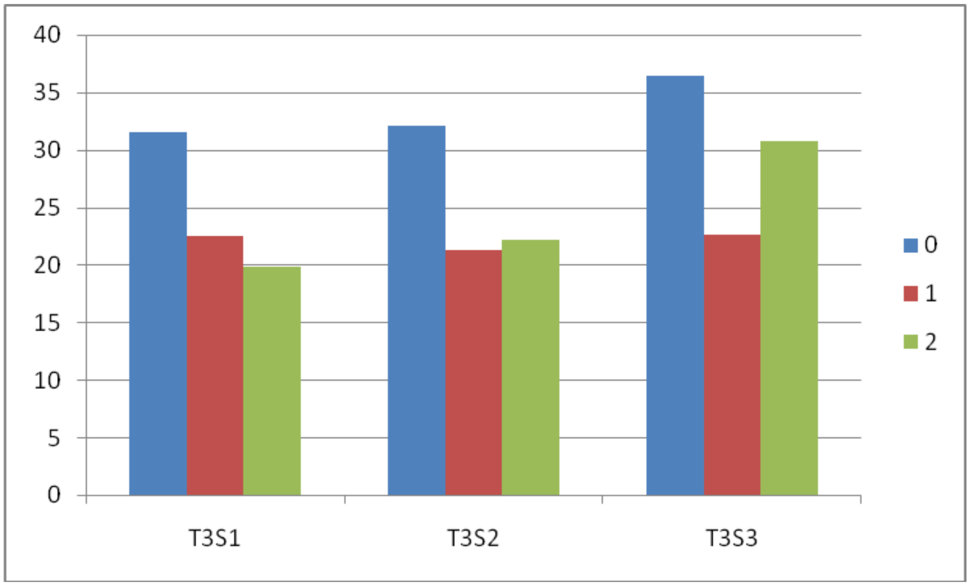

Figure 3. Tensile strength (N/mm^2) values at constant temperature (T_3), varying screw speed and varying filler content.

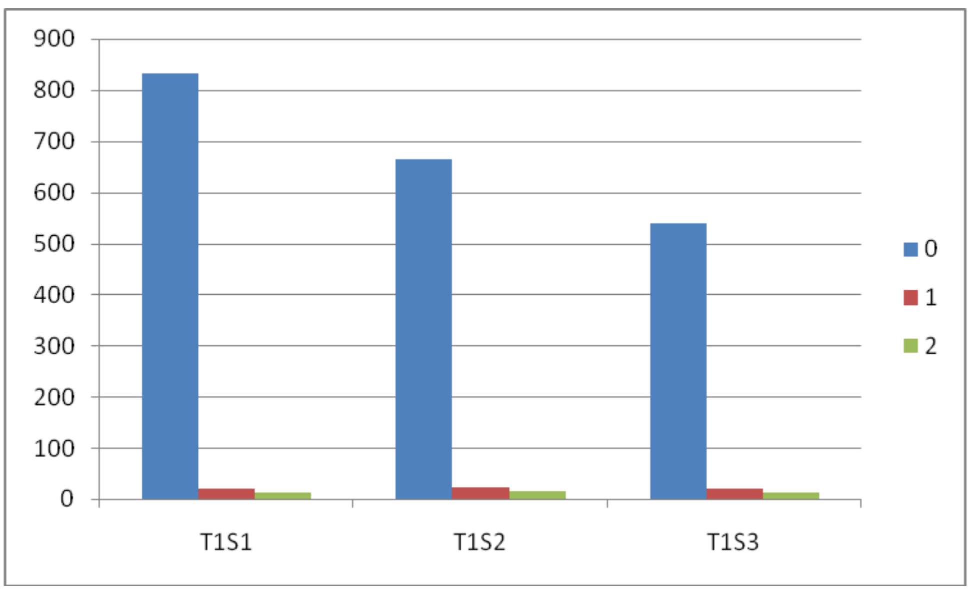

Figure 4. Elongation at break (%) at constant temperature (T_1), varying both screw speed and filler content.

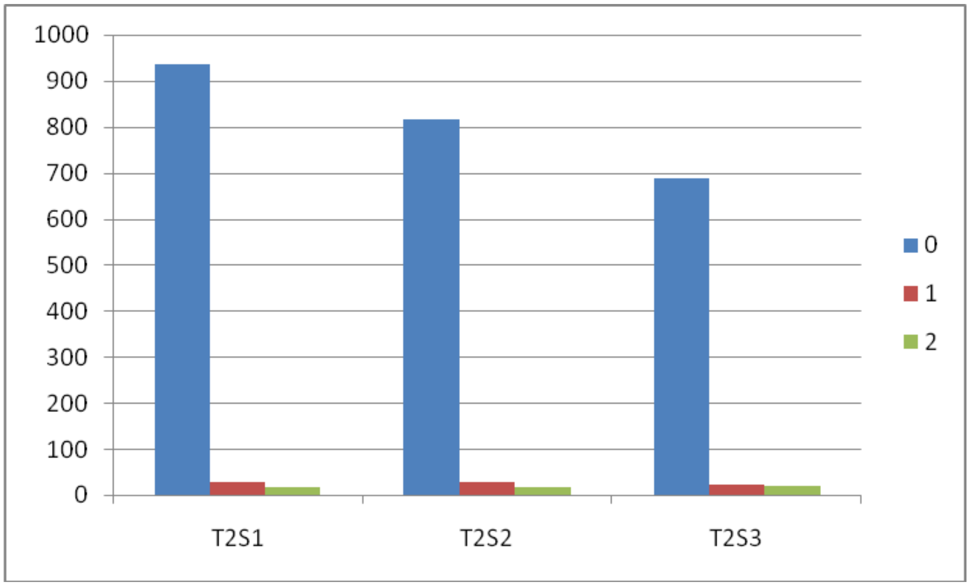

Figure 5. Elongation at break (%) at constant temperature (T_2), varying both screw speed and filler content.

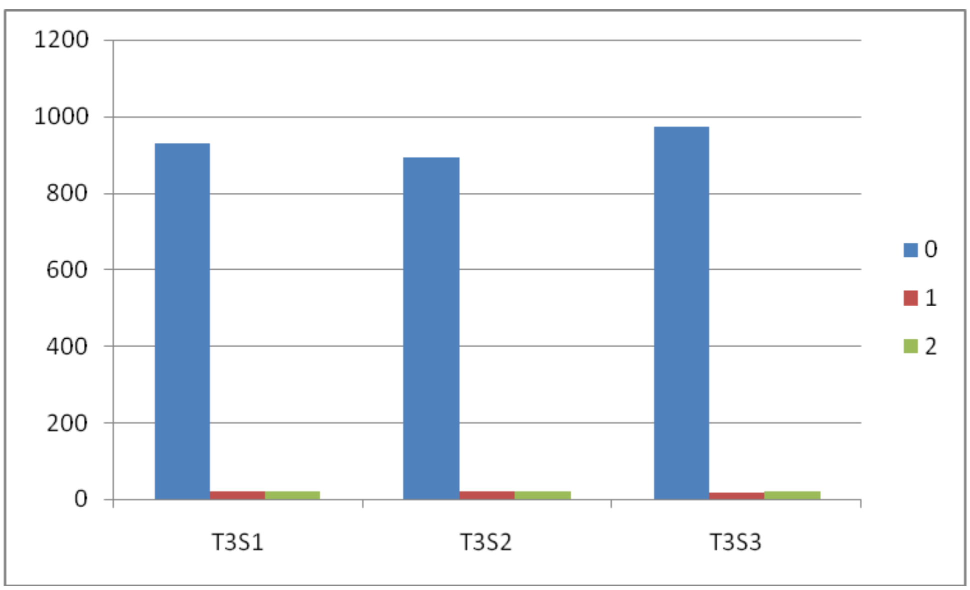

Figure 6. Elongation at break (%) at constant temperature (T_3), varying both screw speed and filler content.

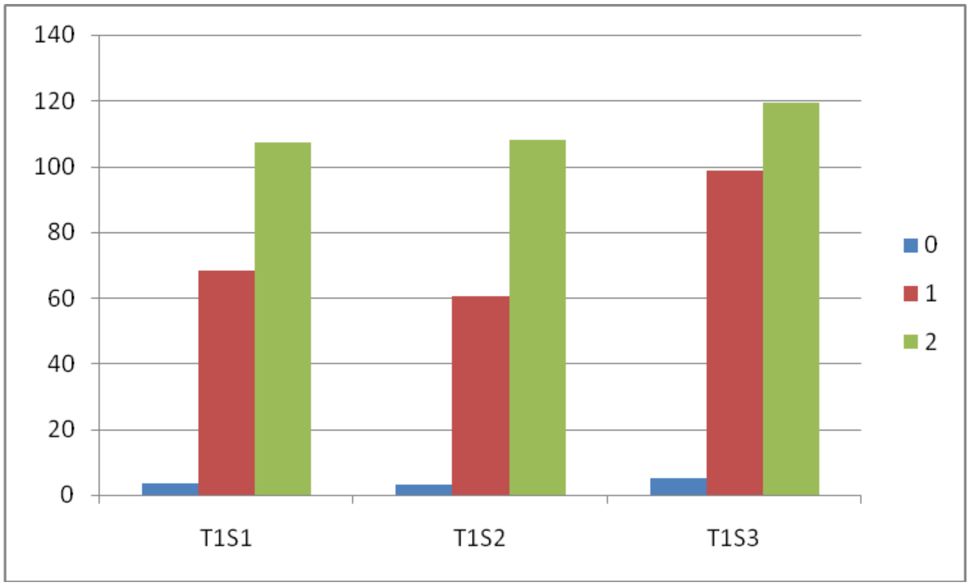

Figure 7. Tensile modulus (N/mm^2) at constant temperature (T_1), varying both screw speed and filler content.

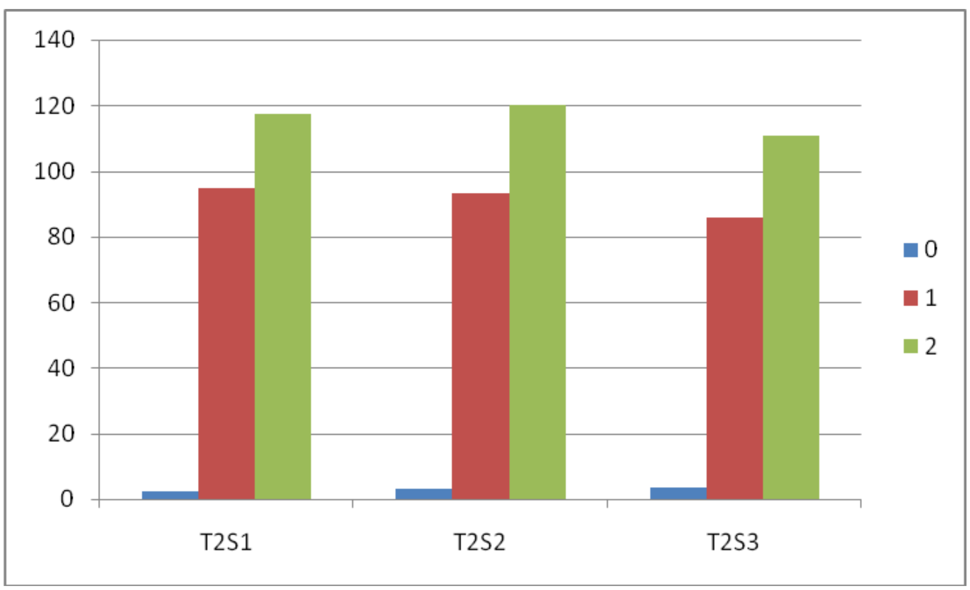

Figure 8. Tensile modulus (N/mm^2) at constant temperature (T_2), varying both screw speed and filler content.

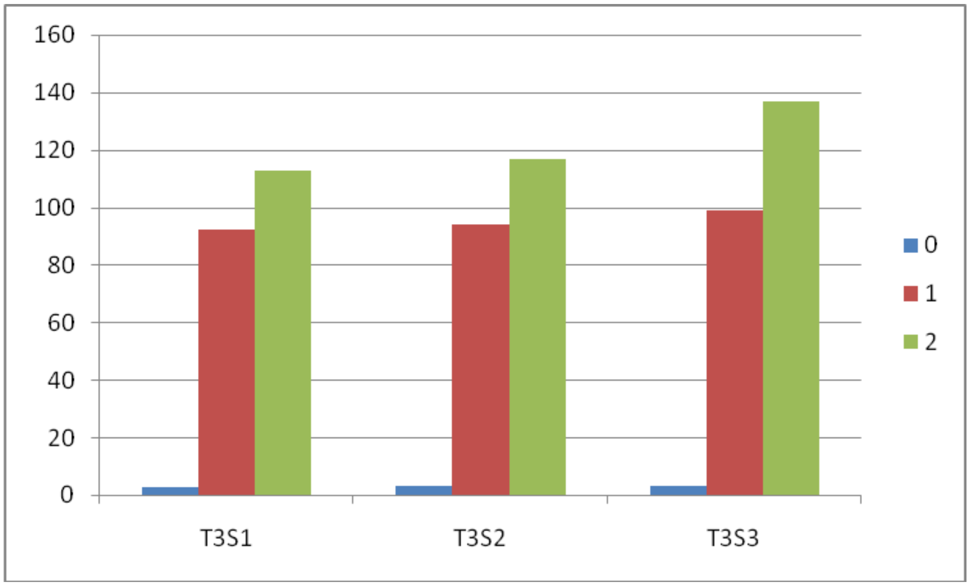

Figure 9. Tensile modulus (N/mm^2) at constant temperature (T_3), varying both screw speed and filler content.

Appendix II

Table 5.1: Physical characteristics of HDPE

Properties	Test methods	HDPE
Solid density	ASTM D1505	0.946g/cm³
M. F. I. @ 190°C/ 2.16Kg	ASTM D1238	0.32g/10min
Grade number		HFG00346
Tensile strength at yield (MD/TD)	ASTM D638	21/23 Mpa
Elongation at break	ASTM D638	600/850 %
Tear strength (Elmendorf) MD/TD	ASTM D1922	0.9/23 g/um
Vicat softening point, ION	ASTM D1525	121 °C

Table 5.2: Physical characteristics of coir (Siaotong et al, 2005)

Density	1.25g/cm³
Tensile strength	220Mpa
Elastic modulus	6Gpa
Elongation at failure	15 – 25%
Moisture absorption	10%

Table 5.3: Formulation of coir-filled HDPE

Sample code	HDPE (g)	Coir (g)	Silicone oil (ml)
F_0	2000	0	0
F_1	1980	20	5
F_2	1960	40	10

Table 5.4: Processing parameters

Code	Fibre content (F) (%)	Temperature (T) (°C)	Screw speed (S) (rpm)
$F_0T_1S_1$	0	150,175,175,175,190	80
$F_0T_1S_2$	0	150,175,175,175,190	100
$F_0T_1S_3$	0	150,175,175,175,190	120
$F_0T_2S_1$	0	150,185,185,185,200	80
$F_0T_2S_2$	0	150,185,185,185,200	100
$F_0T_2S_3$	0	150,185,185,185,200	120
$F_0T_3S_1$	0	150,195,195,195,210	80
$F_0T_3S_2$	0	150,195,195,195,210	100
$F_0T_3S_3$	0	150,195,195,195,210	120
$F_1T_1S_1$	1	150,175,175,175,190	80
$F_1T_1S_2$	1	150,175,175,175,190	100
$F_1T_1S_3$	1	150,175,175,175,190	120
$F_1T_2S_1$	1	150,185,185,185,200	80
$F_1T_2S_2$	1	150,185,185,185,200	100
$F_1T_2S_3$	1	150,185,185,185,200	120
$F_1T_3S_1$	1	150,195,195,195,210	80
$F_1T_3S_2$	1	150,195,195,195,210	100
$F_1T_3S_3$	1	150,195,195,195,210	120
$F_2T_1S_1$	2	150,175,175,175,190	80
$F_2T_1S_2$	2	150,175,175,175,190	100
$F_2T_1S_3$	2	150,175,175,175,190	120
$F_2T_2S_1$	2	150,185,185,185,200	80
$F_2T_2S_2$	2	150,185,185,185,200	100
$F_2T_2S_3$	2	150,185,185,185,200	120
$F_2T_3S_1$	2	150,195,195,195,210	80
$F_2T_3S_2$	2	150,195,195,195,210	100
$F_2T_3S_3$	2	150,195,195,195,210	120

The take up speed was 50 rpm and film thickness was roughly 0.9mm ± 0.3mm.

Table 5.5: Mechanical properties of test samples

S/No	Code	$\square_T$(N/mm^2)	$\square_Y$(N/mm^2)	Y_M(N/mm^2)	E_B (%)
1	$F_0T_1S_1$	35.368	20.130	3.604	831.908
2	$F_0T_1S_2$	25.834	15.990	3.299	663.658
3	$F_0T_1S_3$	32.519	20.160	5.132	339.359
4	$F_0T_2S_1$	25.804	14.587	2.330	936.499
5	$F_0T_2S_2$	29.136	18.615	3.006	817.457
6	$F_0T_2S_3$	27.736	14.450	3.402	689.068

7	$F_0T_3S_1$	31.504	17.780	2.871	929.730
8	$F_0T_3S_2$	32.135	18.750	3.039	892.435
9	$F_0T_3S_3$	36.464	20.410	3.181	972.314
10	$F_1T_1S_1$	16.527	9.965	68.291	20.585
11	$F_1T_1S_2$	13.487	8.270	60.532	21.584
12	$F_1T_1S_3$	22.751	13.860	98.656	19.518
13	$F_1T_2S_1$	25.570	15.480	94.693	26.705
14	$F_1T_2S_2$	16.858	10.200	93.242	26.500
15	$F_1T_2S_3$	23.685	15.020	85.934	23.200
16	$F_1T_3S_1$	22.548	13.585	92.116	20.695
17	$F_1T_3S_2$	21.274	12.905	94.160	21.146
18	$F_1T_3S_3$	22.606	13.630	98.943	17.545
19	$F_2T_1S_1$	16.533	9.970	107.388	13.132
20	$F_2T_1S_2$	18.499	11.180	108.124	14.420
21	$F_2T_1S_3$	16.179	9.985	119.383	11.496
22	$F_2T_2S_1$	19.230	11.700	117.272	16.173
23	$F_2T_2S_2$	19.273	11.820	119.925	15.849
24	$F_2T_2S_3$	16.744	10.745	110.802	18.169
25	$F_2T_3S_1$	19.875	12.090	112.658	18.388
26	$F_2T_3S_2$	22.161	13.500	116.935	20.715
27	$F_2T_3S_3$	30.731	18.465	136.932	18.993

Where $\square_T$ = tensile strength

E_B = percentage elongation at break

Y_M = tensile modulus

$\square_Y$ = yield strength