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Environmental Sanity by Recycling of Waste Polypropylene Products and Waste Coir Fibre on the Mechanical Properties as Compared to Virgin Polypropylene: A Case Study of Kaduna Polytechnic Tudun Wada

Dina Isa[1*], Agbohor Victor[2], Okele Abdulwahab[3]
*[1]Department of Textile Technology, Kaduna Polytechnic, Kaduna
[2]Department of Chemistry, Kaduna State University, Kaduna
[3]Department of Polymer Technology, NILEST, Zaria
*Email: Isa2dina@mail.com; Tel.: 08036986702

ABSTRACT
A study of the effects of waste coir and waste polypropylene on the mechanical properties of virgin polypropylene was investigated. The coir fibres (filler) were treated with NaOH to improve properties and enhance better adhesion between matrix (PP) and filler (coir fibre) before compounding it with waste PP which was washed and crushed. Virgin PP was obtained and blended with the waste PP to determine best ratio blends. The filler was weighed and combined with waste PP into a 100mm x 100 mm x 3mm composite. Mechanical tests such as tensile, flexural, impact and hardness Shore D were carried out to determine best possible blend ratios and end uses.

Keywords: *polypropylene, coir fibres, recycling, mechanical properties*

INTRODUCTION
Due to highly increasing number of plastic from everyday use such as commodity plastics like polyethylene bags, disposable cups, plates, containers, chairs, electronic parts to engineering plastics used to replace metal parts in cars, airplanes, boats, televisions, toys has led to a lot of plastic waste. There is a concerning need on a way to properly dispose those used plastics to avoid sewage blockages, plastics filling the land fill, cause water and land pollution which may later directly or indirectly have a side effect on human, animals and marine life around the globe. Recycling of the above listed plastics, can be away to help reduce the waste plastic pollution, blockages of sewage and water ways that may cause flooding and accumulation of dirt around the society. Also this can help to give jobs opportunity, educating people on how to sort out the plastics using the resin identification codes to people around to going round the landfills, house, and dump sites, collecting these plastics wastes, and transporting them to the nearest plastic industry for recycling into new products or incorporating it into a similar used product[1].

PP is a thermoplastic polymer widely used in many different applications including automotive component, reusable containers of different types, plastic parts, packaging and labelling. PP is rugged and resistant to different chemical solvents, acids and bases. PP is resin recycling code is 5 and is recyclable. The melting point and strength of PP makes it the single most used plastic packaging in the United States and UK, with approximately 5 billion pounds produced in 2010 alone in the USA because of the short life span of PP made end up in the landfills as waste. The environmental Protection agency states that approximately 20% of solid waste produced comprises some form of plastics which include PP. Products made from PP degrade slowly in landfills and takes approximately 20 – 30 years to get completely decomposed. This pose a severe effect on our environment mainly because of additives contain many toxins such as lead and cadmium. Burning of thermoplastics like PP can discharge venom like dioxins and vinyl chloride and thus makes environmental pollution resulting as PP burning a serious issue.

PP recycling process involves five steps namely; collection, shortening, cleaning reprocessing by melting and producing new products from recycled PP. The first three steps are the same for most recycling of other products. The last two processes are critical .in reprocessing phase collected PP products are fed into an extruder where it is melted at 464 °F (240 °C) and are cut into little granules. These granules are then ready for use in production of new products. Recycling of mixed plastics waste is the next major challenge for the plastics recycling sector. The advantage is the ability to recycle a larger proportion of the plastic waste stream by expanding post- consumer collection of plastic packaging to cover a wider variety of materials and pack types. Product design for recycling has strong potential to assist in such recycling efforts. A study carried out in the UK found that the amount of packaging in a regular shop- ping basket that, even if collected, cannot be effectively recycled, ranged from 21 to 40% Local Government Association (UK) 2007. Wider implementation of policies to promote the use of environmental design principles by industry could have a large impact on recycling performance, increasing the proportion of packaging that can economically be collected and diverted from landfill[3]. The same logic applies to durable consumer goods designing for disassembly, recycling and specifications for use of recycled resins are key actions to increase recycling. Plastic films are currently recycled from sources including secondary packaging such as shrink-wrap of pallets and boxes and some agricultural films, so this is feasible under the right conditions.

Coir fibres are natural fibres and gaining popularity in many sectors especially in the automotive industries. Natural fibres have many distinctive advantages over other fillers with its limitless application area. The reinforcing constituent is embedded in a matrix to form the composite. Composite structures are quite common in nature where fibres and matrices are combined. Coir fibres are widely used along side with rubber, thermoset and thermoplastic resins to make polymer composites.

MATERIALS AND METHODS

The materials used for this research are: Virgin polypropylene, Waste polypropylene, Coir fibres, Mould, Foil paper, $KMnO_4$ solution, Acetone, Lubricating oil

The equipment used are: Compression moulding machine. (Hydraulic press machine, 1190); Crushing machine. (C.M, 9812). New Jersey; Two –Roll Mill. (Reliable 5189). New Jersey; Impact Tester. (Ceast 6957); Electronic Weighing Balance. (HC-D) Golden-mettler U.S.A; Tensometer (9875). Monsanto. USA; Hardness tester, Muver Franscisco, (5019) Munoz Irles

Table 1: The composition of virgin PP and waste PP composite

S/No	Virgin PP (Wt grams)	Waste PP (wt grams)
1	100	0
2	75	25
3	50	50
4	25	75
5	0	100

Table 2: the composition of waste PP and treated coir fibres composite

Samples	Waste PP (wt grams)	Untreated coir fibres (wt grams)
1	100	0
2	90	10
3	80	20
4	70	30
5	60	40

Methods

Coir fibre treatment

The coir fibres were treated with aqueous sodium hydroxide. The retting process which is a curing process during which an environmental partial decomposition of the pulp separate into coir fibres and a residue called coir pith. The coir fibres were soaked in 10 litres of distilled water to clean the fibres of any residues after which the coir fibres were dried for 3 days to remove out any moisture. The dried coir fibres were then immersed in a 5 % aqueous NaOH solution for 72 hours at room temperature for proper depolymerisation of cellulose removal of the lignin to enhance better adhesion properties with the matrix.

After the treatment, the treated coir fibres were carefully spread out on a mat and then air dried for 3 days. Then the coir fibres were dipped in a permanganate solution at a concentration of 50 % acetone for 10 minutes for neutralization of the alkaline treated coir fibres and hence the hydrophilic tendency of the coir fibres and water absorption of the coir fibres composite are expected to decrease.

Sample weighing

All samples were weighed using the Electronic Weighing Balance in ratios shown in Tables 1 and 2 and labelled properly for identification.

Mixing and compounding process

The compounding process for the mixing of virgin PP and waste PP were done on the two-roll mill machine where the front and rear rollers can be heated at varying temperatures. The machine was allowed to heat up for 15 minutes at a temperature of 170 °C before introducing the materials in between the rolls. Table 1 samples (virgin PP/waste PP) were first molded into 100mm x 100 mm x 3 mm at 170 °C to attain a high consistency before it was removed and allowed to cool down. Same procedure was carried out for all samples (waste PP/ waste treated coir fibres) using Table 2 to compound the composites.

Tensile Test

The tensile test was carried out on all ten composite samples. The test specimens were conditioned under standard conditions of relative humidity of 50 ± 5 percent and room temperature of 24 °C before testing. The test specimens were cut with a hand saw into dumbbell shapes of the following dimensions 100 mm x 15 mm x 10 mm for the inner gauge length. The test samples for all 10 composites were tested according to ASTM D638 using the Tensometer (Monsanto, 9875) at cross head speed of 10 mm/minute.

The samples were tested three times each and the mean average value was calculated and recorded. The tensile strength at break, tensile modulus and elongation at break were calculated from the following equations:

$$\text{Tensile Strength} = \frac{\text{Breaking Force}}{\text{Original Cross sectional Area}}$$

$$\text{Tensile modulus} = \frac{\text{Stress}}{\text{Strain}}$$

$$\text{Elongation at break} = \frac{\Delta L}{L} \times 100$$

where ΔL is the change in the original length and L is the original gauge length

Flexural test

The flexural bending test is a measure of stiffness and was done in accordance with ASTM D-790 with the tensile Tester Monsanto (Model 9875) at a cross head speed of 5mm/min. The samples for both the pressure pipe and sewage pipe were cut into 30mm x 40mm (3mm thick). The flexural strength and the flexural modulus were determined using the following equations.

$$\text{Flexural Strength} = \frac{3PL}{2bt^2}$$

$$\text{Flexural Modulus} = \frac{PL^3}{4bt^3w}$$

Where, L is the span length of the sample. P is the load applied, b and t are the breath and thickness of the specimen respectively and w is the deflection.

Impact test

The impact strength is a measure of the energy needed to break the sample on impact. The samples were cut into 10 mm by 100 mm (3 mm thick) to fit into the impact testing machine. The test was carried out on all samples according to ASTM E23. All samples were subjected to a velocity impact of 4 Joules and a weight of 2 kg with an inclined hammer at an angle of 150°. Seven replicate specimens were tested and the results were calculated using the mean average of the seven readings and the average was recorded.

Hardness test

Hardness is the resistance of a material to deformation, indentations or scratching. The tests were performed to determine the hardness of all samples using the Shore hardness (Muver Fransisco, Munoz). The tests were done according to ASTM E2240. Each sample was tested on the hardness tester (Muver) while in the compressed molds form of 100 mm x 100 mm (3 mm thick) and subjected to seven hardness readings at different positions on the samples. The average was calculated using the mean of the seven readings for each sample and was recorded.

RESULTS AND DISCUSSION

Tensile test (tensile strength and tensile modulus)

The tensile strength of a material is the maximum load applied to a specimen in stretching it to rapture. Table 3 shows the result of the tensile test for virgin PP/ waste PP

Table 3: Tensile Strength of virgin PP/ waste PP

Samples (recyclates/waste PP grms)	Tensile strength N/mm^2
100/0	39
75/25	38
50/50	36
25/75	34
0/100	31

Results from Table 3 showed that the tensile strength of the composite decreases as the amount of waste PP increases. This can be due to the fact that the inhomogeneous of the waste PP collected from Kaduna polytechnic school premises may have encountered slight loss of mechanical strength from sunlight, rain and atmospheric change over a period of time. Also, no account can be given to as how long the waste PP have been left out in the dumpsites.

Table 4: Tensile Strength of waste PP/ treated coir fibres

Samples waste PP/ treated coir fibres grms	Tensile strength N/mm^2
100/0	31
90/10	33
80/20	34.5
70/30	35
60/40	35.5

Table 4 shows the tensile strength of the waste PP and the treated coir fibres show a decrease in tensile strength, in order to increase the compatibility of the coir they were chemically treated with sodium hydroxide and later neutralized with potassium per manganite solution. These results suggest that stress is expected to transfer from matrix to fibre, indicating a better interfacial bonding with a consequent improvement in the mechanical properties. The young modulus of the waste PP/ treated coir fibres showed an increase with an increase in fibre loading and this can be seen with other researchers Yang *et al*, 2004 and Lou *et al*, 2007. During tensile loading, partially separated micro- spaces are created, which obstruct stress propagation between fibre and matrix as explained by Joseph et al, 2002.

flexural properties

Table 5: flexural strength of waste PP/treaded coir fibres

Sample of waste PP/treated coir fibres (grms)	Flexural strength MPa
100/0	53
90/10	55
80/20	56
70/30	58
60/40	58.5

From Table 5, Flexural strength and modulus of the waste PP/treaded coir fibres increase with different ratios of fibre loading as also reported by Joseph *et al*, 2002. Since the coir fibres yielded high modulus compared to untreated coir fibres as seen with order researchers Rana et al, 2003. This can be explained by the higher fibre concentration demand which in turn demand higher stress for the same deformation. Increased fibre- matrix adhesion provides increased stress for the same deformation.

Hardness Shore D

The hardness test results showed that the virgin PP composite had the best hardness values compared to both the added waste PP and treated coir fibres composite. This result is expected because the virgin PP has no fillers and no contamination.

Table 6: Hardness shore D results virgin PP/waste PP

Samples	Virgin PP/waste pp	Hardness Shore d
A	100/0	95
B	75/25	94
C	50/50	90
D	25/75	87
E	0/100	83

Table 6 shows a decrease in the hardness Shore D from 100% virgin to 100% waste. From the results seen from Table 6, it shows that the hardness of the composites decreases because the waste PP has suffered slight degradation from outside conditions and possible lack of uniform shredding and crushing could attribute to the decrease in the hardness value.

Table 7: hardness shore D results virgin PP/waste PP

Samples	waste PP treated coir fibres	Hardness Shore d
A	100/0	83
B	90/10	84
C	80/20	85
D	70/30	87
E	60/40	88

Results from Table 7 show the hardness of various manufactured composites at different fibre loading for coir fibres. This results is similar to findings by Mishra *et al*, 2000 who observed that there was an increase in stiffness of the respective composites for treated coir fibres using benzene diazonium salt to improve compatibility with the PP matrix. This is due to increase in stiffness of the coir fibres with the matrix.

Impact tests

Results from the impact strength results showed a decrease from 100% virgin PP to 100% waste PP, such results are expected because results from both tensile tests and flexural show that as the amount of waste PP is added, there is loss of mechanical properties but in the case of added coir fibres to the waste PP, it can actually improve hardness and impact strength. These findings are significant in the recycling of waste PP with waste treated coir fibres. It has been reported that the high fibre content increases the probability of fibre agglomeration, which results in regions of stress concentration requiring less energy for crack propagation as seen by Mishra, 2000.

CONCLUSION

In the current work, coir fibre reinforced PP composites were compounded using the two- roll mill and compression molding machine to produce a composite from waste PP and waste treated coir fibre in Kaduna Polytechnic as environmental clean-up strategy to convert wastes into wealth by determining the best amount of treated coir fibres to be in cooperated into the waste PP to get desired result and this was compared to experiment carried out alongside using virgin PP and blending same waste to get the best blend ratios to possible avoid buying of new PP and keeping the surrounding clean. Significant improvement of mechanical properties such as hardness, flexural modulus and impact strength were observed after chemical treatments of coir fibres. However, at 30% treated coir fibres remains the best blend ratio for the composite and its best recommended for reuse of goods such as table and kitchen mats, window shields e.tc.

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