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The Effect of Coffee Husk Waste Addition with Alkalisation Treatment on the Mechanical Properties of Polypropylene Composites

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ABSTRACT. Indonesia is the fourth largest coffee-producing country in the world, with 762.38 thousand tonnes of production in 2020. The coffee bean waste in the form of coffee skins is around 50-60% of the harvest. Coffee skin waste is a natural material that has not been widely used. Processing coffee skin waste as a filler in thermoplastic polymers can solve environmental problems. This study uses the polypropylene matrix. This study was conducted to determine the effect of adding coffee husk by alkalizing treatment on polypropylene composites on tensile strength, impact strength and flexural strength. The composition of coffee husk used is 20, 30, and 40% wt. The coffee husk was first alkalized with 5%, 8%, and 11% KOH to remove lignin. Composite manufactured using manual forming machines. These results indicate that adding coffee husk reduces the value of the tensile strength and flexural strength of the polypropylene composite. Adding 20% wt coffee husk with 5% KOH alkalisation on the polypropylene composite gave the highest tensile strength value of 5.65 MPa and the highest flexural strength of 28.72 MPa. Alkalisastion treatment with KOH on coffee husk reduces the value of tensile strength and flexural strength in polypropylene composites. The treatment without 0% KOH alkalisation on the coffee husk gave the highest tensile strength value of 13.30 MPa and alkalizing treatment with 5% KOH on the coffee husk gave the highest flexural strength value of 28.72 MPa with the addition of 20% wt coffee husk. Alkalisastion treatment with KOH on coffee husk increased the impact strength value on polypropylene composites. Alkalisastion treatment with 11% KOH on the coffee husk gave the highest impact strength value of 4.62 kJ/m^2 with the addition of 20% wt coffee husk.

1. INTRODUCTION

Coffee is a high-value commodities product derived from coffee beans. Coffee is one of the most popular beverages in the world, and its commercial significance has expanded significantly over the past 150 years. According to the International Coffee Organization (ICO) figures, Brazil was the world's most significant coffee producer in 2015-2017. The average production in April 2017 was 3,300,300 tonnes, representing 36.27 % of the global coffee output. Indonesia is fourth, producing 600,000 tonnes, or 6.60% [1]. From 2019 to 2021, coffee production is anticipated to grow. In 2020, coffee production will increase by 1.31%, from 762.38 thousand tonnes in 2019 to 762.51 thousand tonnes in 2020. In 2021, coffee production will increase by 3.12 %, or 786.19 thousand tonnes [2].

Depending on the processing method, coffee processing generates substantial agricultural waste, approximately 30–50%wt of the coffee produced [3]. Coffee bean waste results in coffee skins, which account for 50 to 60 % of the harvest. If the yield is one thousand kilogrammes of fresh coffee with skin, about four hundred to five hundred kilogrammes will be coffee beans, and the remainder will be coffee skin [4]. Recent research has concentrated on identifying other uses for coffee industry waste to lessen environmental effects. Coffee by-products contain between 16.0 and 25.0% cellulose fibre, 9.0 and 11.0% hemicellulose, and 6.0 and 10.0% lignin [5]. As fillers in thermoplastic polymers, coffee husks have proven useful. Coffee husks can be employed as fillers in composites with low density, superior thermal insulation, great mechanical qualities, and low cost [6]. The addition of 70% coffee husk to HDPE polymer increased its tensile strength to 44.5 MPa and its flexural strength to 69.6 MPa, according to research [7]. Adding 20% coffee husk and 2% MAPP addition to polypropylene polymer increased its tensile strength to 31.2 MPa and its flexural strength to 47.4 MPa, according to research [8]. In a study [9], the tensile strength of polypropylene polymer was increased to 34,1 MPa by adding 5% coffee husk and 3% NaOH.

A Composite is a blend of two or more materials whose physical or chemical properties are distinct, creating new materials. Composite elements consist of filler or reinforcement and matrix [10]. This study's matrix is composed of polypropylene. Polypropylene (PP) is a thermoplastic polymer commonly found in household and industrial applications. Polypropylene can be utilised as the primary material for polymer-based composites due to its mechanical qualities, which include strength, hardness, chemical resistance, the ability to be coloured, and affordability [11]. Polypropylene is a matrix material for natural fibre-reinforced polymer composites due to its resistance to high-effect loads. Due to its high cellulose and lignin content, coffee husk waste can be considered as a filler for polymer composites. It is one of the natural fibres yet to be thoroughly investigated.

Alterations on the fibre surface need to be carried out to obtain a satisfactory bond between the fibre and the matrix; modifications on the fibre surface are carried out by alkaline treatment. Natural fibres treated with alkali improve the composite's mechanical properties, such as strength, stiffness, and dynamic flexural modulus, showing matrix-fibre adhesion [12]. The process of alkalisation involves immersing fibre in an alkaline solution. Lithium Hydroxide (LiOH), Sodium Hydroxide (NaOH), and Potassium Hydroxide are examples of alkaline bases (KOH). KOH is more electronegative than NaOH. Hence more lignin can be identified when added alkaline KOH. The link between concentration and lignin degradation efficiency indicates that the higher the concentration of pretreatment bases, the greater the lignin degradation efficiency [13].

All natural plant fibres have hydrophilic qualities in contrast to the hydrophobic features of polymers. Alkalisation treatment can diminish the hydrophilic qualities of natural fibres so that natural fibres have compatibility with polymeric materials. In addition, the alkalisation procedure removes extractive components from natural fibres, such as lignin, pectin, wax and contaminants, to produce natural fibres with reasonably uniform surface topography [14]. Andretta and Irfa'i studied the effect of KOH solution alkalisation on hemp and epoxy composites' tensile strength [15]. The immersion effect of Potassium Hydroxide (KOH) solution on composites with the most excellent tensile test results compared to fibres without KOH alkalisation treatment enhanced the tensile strength value. Without KOH alkalisation treatment, the tensile strength of untreated fibres was 14.12 MPa, while fibres treated with 5% KOH achieved the greatest tensile strength of 36.83 MPa. In the study [16], the KOH alkalisation treatment on coco fibre added to polyester polymer resulted in variable tensile strength. The tensile strength without alkalisation treatment was 1.41 MPa, and the 5% alkalisation treatment was 5.29 MPa. The tensile strength increased at treated with 10% alkalization (6.29 MPa) and decreased at treated with 15% alkalization (3.50 MPa). The purpose of this study was to determine the effect of adding coffee husk waste with alkalisation treatment to polypropylene composites on tensile strength and flexural strength, as well as the effect of varying the percentage of coffee husk waste alkalisation with KOH added to polypropylene composites on tensile strength, effect strength, and flexural strength.

2. MATERIALS AND METHOD

2.1 Materials

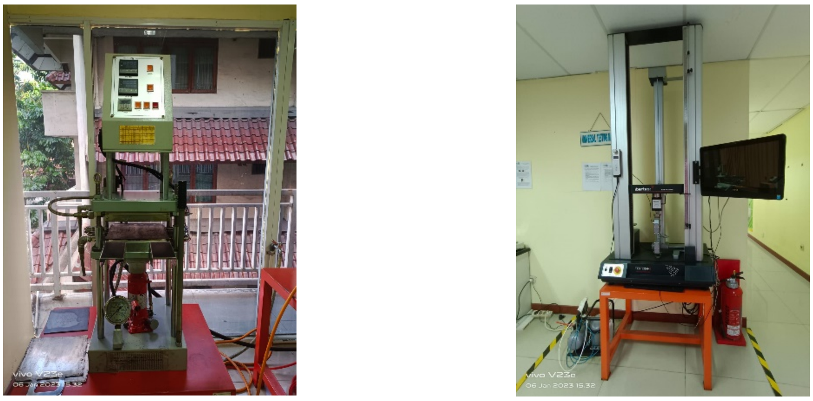
The polymer matrix utilised is PT Chandra Asri Petrochemical Tbk's PP Homopolymer H1010. The filler is a mixture of ground-up coffee husk waste. Other materials used are KOH solution with the MERCK brand and aqua dest. Manual Forming Machine, Pneumatic Specimen Punch, Universal Testing Machine (UTM), Izod Notch, filter, digital balance, and oven are utilised. The research variables are displayed in Table 1.

Table 1. Research variables

No	Composition, %weight		Alkalisation with KOH (%concentration)
	Coffee husk waste	Polypropylene	
1	20	80	5
2	30	70	5
3	40	60	5
4	20	80	8
5	20	80	11

(a) (b)

Figure 1. a) coffee husk before grinding, b) coffee husk after grinding



(a) (b)

Figure 2. a) *Manual Forming Machine* (MFM), b) *Universal Testing Machine* (UTM)

2.2 Material preparation

With a blender and a 40-mesh filter, the coffee skin is ground. Four hours were spent soaking coffee skins in a 5% KOH alkaline solution. After soaking for 4 hours, the coffee skins were rinsed with distilled water until the pH returned to normal to eliminate residue from soaking the alkaline KOH compounds. The pH-balanced coffee skins are dried in an oven at 80^{o}C until their weight is constant.

2.3 Process for Making Coffee Skin Waste Composites

The prepared material is put in, and the composite is created using a 20cm x 20cm x 0.2mm Manual Forming Machine with a 20cm x 20cm x 0.2mm mould. As an initial layer, weighed polypropylene pellets are placed onto a metal pallet until equally dispersed. In addition, the alkalisation-treated coffee husks are poured onto a pallet pre-coated with polypropylene pellets, filling all sides of the metal pallet. The polypropylene pellet is reapplied over the coffee husk as a finishing layer. The composite material was crushed with a pressure of 300 kg_f/cm^2 at 195°C for 25 minutes.

The completed composite sheets were formed into dog bone specimens using a Pneumatic Specimen Punch machine with a pressure of 5 bar. Each composite sheet is produced of 5 test specimens which will then be evaluated for tensile and flexural strength using the Universal Testing Machine (UTM). Effect strength is tested using Izod Notch

2.4 Testing

The tensile strength test was carried out at the Polymer Instrumentation Laboratory, Polytechnic STMI Jakarta. According to ASTM D-638, five dog bone specimens were made for the tensile test and then conditioned for 40 hours at a room temperature of around 23°C before testing the tensile strength using the Universal Testing Machine (UTM), effect strength test under ASTM D-256 and flexural strength test under ASTM D-790 carried out at the Polymer Technology Laboratory, National Research and Innovation Agency.

3. RESULTS AND DISCUSSION

3.1 The Effect of coffee husk waste incorporation on the tensile strength of polypropylene composites

The test results for tensile strength are displayed in Table 2 and Figure 3. The data indicates that the composite's performance decreases as the volume of filler increases. Adding 20%wt of coffee husk waste increased the tensile strength to 5.65 MPa, and adding 30%wt of coffee skin waste dropped the strength to 5.52 MPa. Similarly, adding 40% coffee husk waste reduced the composite's tensile strength to 4.99 MPa.

Table 2. Variation of the addition of coffee husk waste to the tensile strength of polypropylene composites

Coffee husk waste (%weight)	Tensile strength (MPa)					
	1	2	3	4	5	Average
20	6.4	8.36	6.09	2.74	4.64	5.65
30	5.13	3.88	6.49	3.69	8.4	5.52
40	4.13	7.85	4.95	6.28	1.77	4.99

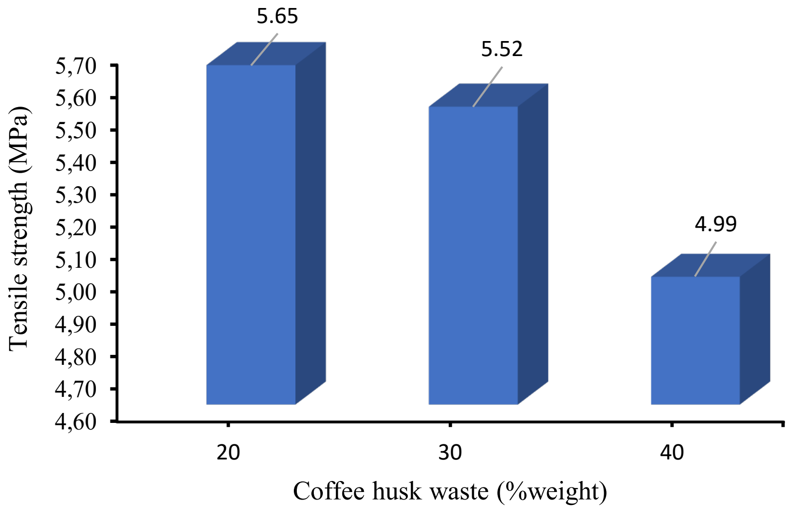


Figure 3. Variation of the addition of coffee husk waste to the tensile strength of polypropylene composites

The tensile strength value is decreasing and affected by the increase in the composition of the coffee husk waste in the composite. This study is in line with the results of research conducted by [8] regarding the addition of 20% coffee husk and 2% MAPP additive to polypropylene polymers resulting in the highest tensile strength of 31.2 MPa and the addition of 30% coffee husk and 3% MAPP additive lowered tensile strength, this equals 29.6 MPa. The composite's tensile strength decrease is caused by the increasing composition of the fibre filler utilized. The lower the tensile strength value of the composite, the coffee husk waste as a filler may have an uneven contribution to the matrix resulting in low tensile strength.

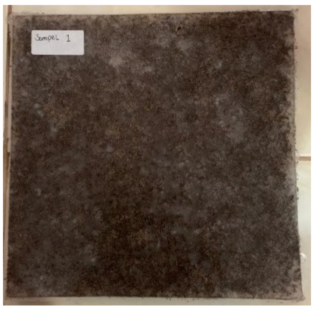


Figure 4. Composite of coffee husk waste in polypropylene polymer

Due to the existence of voids in the matrix, the composite strength has diminished, resulting in a decline in composite quality. Voids or air bubbles in the composite considerably affect the composite quality because voids can create stress concentrations when the composite product gets a force, with more and more voids forming, it signals a decline in the matrix quality of the composite.

3.2 The Effect of coffee husk waste incorporation on the flexural strength of polypropylene composites

The flexural strength test results are displayed in Table 3 and Figure 5. A decrease in the data accompanies each reduction in filler volume in the composite. The addition of 20%wt of coffee husk waste obtained a flexural strength value of 28.72 MPa, and the strength reduced after adding 30%wt of coffee husk waste was 26.68 MPa.

Table 3. Variation of addition of coffee husk waste composition to the flexural strength of polypropylene composites

No	Coffee husk waste (%weight)	Flexural strength (MPa)
1	20	28.72
2	30	26.68

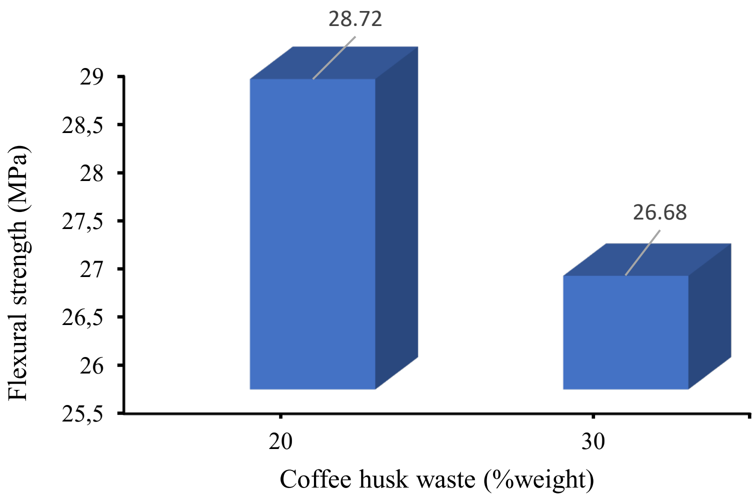


Figure 5. Variation of addition of coffee husk waste composition to the flexural strength of polypropylene composites

The composite of coffee husk waste and polypropylene with 20%wt of coffee husk waste had the maximum flexural strength. According to [17], the lower flexural strength results from the inhomogeneous shape and somewhat random distribution of the fibres, which disrupts the link between the matrix and a filler powder. If evaluated from a visual point of view in fibre-reinforced composites, the smaller the fibre size tends to experience agglomeration, and the distribution of fibres in the matrix substantially affects the mechanical strength of the composite.

3.3 The Effect of altering the percentage of coffee husk waste alkalisation with KOH on the tensile strength of polypropylene composites

The test results for tensile strength are displayed in Table 4 and Figure 6. The tensile strength of the composite of coffee husk waste and polypropylene 20:80%wt are 13.30 MPa (without KOH alkalisation), 5.65 MPa (5% KOH), 10.71 MPa (8% KOH), and 12.15 MPa (11% KOH). The alkalisation process modifies this strength with KOH, which can improve the tensile strength. The composite made from coffee husk waste treated with 11% KOH was stronger than composites treated with 8% and 5% KOH. However, the composite without alkalisation had the highest value compared to those treated with 11% KOH.

Table 4. Variation of percent alkalisation with KOH on tensile strength

KOH concentration (%)	Tensile strength (MPa)					
	1	2	3	4	5	Average
0	7.92	18.25	19.83	9.68	10.81	13.30
5	5.13	8.36	6.09	2.74	4.64	5.65
8	7.80	8.87	10.36	13.51	13.00	10.71
11	16.41	8.62	9.91	11.99	13.83	12.15

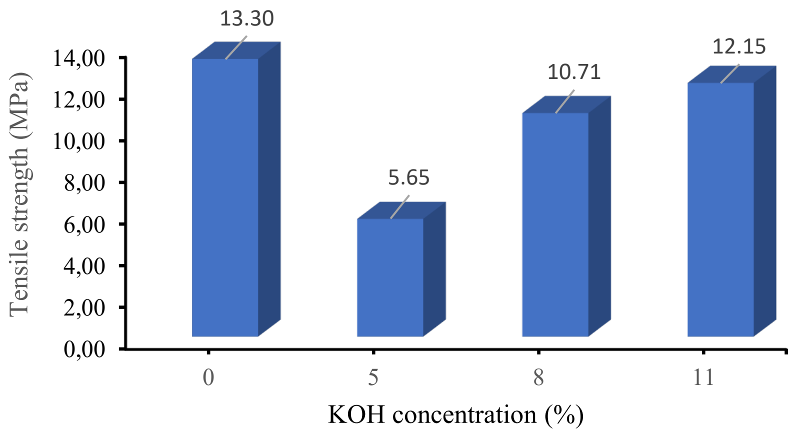


Figure 6. Variation of percent alkalisation with KOH on tensile strength

The tensile strength value without KOH alkalisation treatment is 13.30 MPa. It is higher than the composite with varying percentages of KOH alkalisation. However, alkalisation with KOH increased the tensile strength of coffee husk waste. The hydrophobicity of coffee husk waste increased because the KOH alkalisation improved the interaction between matrix and fibre. It was unable to compensate for the decrease in tensile strength due to structural damage (dissolution of hemicellulose, lignin, and pectin), as explained by Syafri et al. [14]. According to [18], prolonged treatment of natural fibres might cause harm to the fibre structure.

3.4 The effect of altering the proportion of coffee husk waste alkalisation with KOH on the impact strength of polypropylene composites

The impact strength test results are displayed in Table 5 and Figure 7. The impact test revealed that the composite's impact strength was 2.77 kJ/m^2 (without KOH alkalization), 4.16 kJ/m^2 (5% wt KOH alkalization), and 4.62 kJ/m^2 (11% wt KOH alkalization). The link between KOH alkalisation and impact strength has strengthened, as seen in Figure 7. The highest impact strength was obtained with 11% KOH alkalisation, whereas the lowest was obtained with KOH alkalisation.

Table 5. Variation of percent alkalisation with NAOH on impact strength

No	KOH concentration (%)	Impact strength (kJ/m^2)
1	0	2.777
2	5	4.168
3	11	4.625

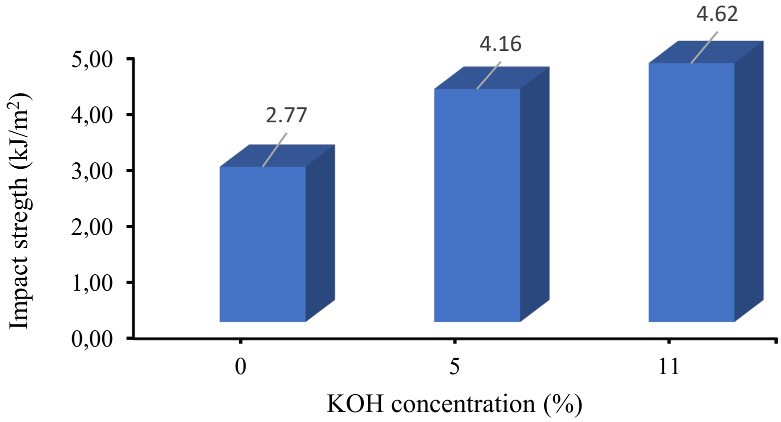


Figure 7. Variation of percent alkalisation with NAOH on impact strength

The composites with an 11% KOH alkalisation had the maximum impact strength (4.62 kJ/m^2) compared to composites without KOH alkalization (2.77 kJ/m^2). The improvement in impact strength of polypropylene composites with KOH alkalisation on coffee husk waste was attributable to the composite's bonding strength, which aids in retaining the applied load [19].

3.5 The Effect of altering the percentage of coffee husk waste alkalinisation with KOH on the flexural strength of polypropylene composites

The flexural strength test results are reported in Table 6 and Figure 8. The flexural strength test determined the composite's flexural strength to be 26.98 MPa (without KOH alkalisation), 28.72 MPa (5% KOH alkalisation), 24.41 MPa (8% KOH alkalisation), and 26.60 MPa (11% KOH alkalisation). Figure 8 demonstrates that the link between alkalisation treatment variations and flexural strength has diminished, with the 8% KOH alkalisation treatment having the lowest flexural strength and the 5% KOH alkalisation treatment having the maximum flexural strength.

Table 6. Variation of percent alkalisation with KOH on flexural strength

No	KOH concentration (%)	*Flexural Strength* (MPa)
1	0	26.98
2	5	28.72
3	8	24.41
4	11	26.60

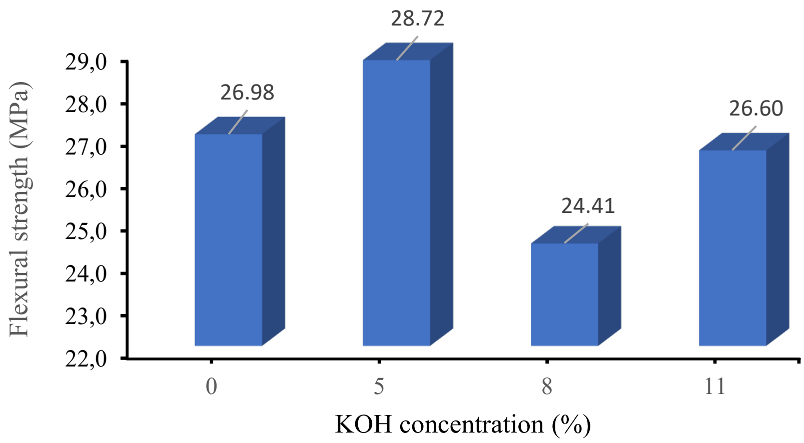


Figure 8. Variation of percent alkalisation with KOH on flexural strength

The alkalisation treatment of coffee husk waste affects the flexural strength of the manufactured composites. According to the research findings, the 5% KOH alkalisation treatment produced the greatest flexural strength. In research [20] on polyester matrix composites, the maximum flexural strength values were generated at 5% alkalisation and the lowest at 20% alkalisation. This is due to the necessary alkali treatment that damages the polyester matrix; this affects the flexural strength value even if the fibre has been alkalised. This is also consistent with studies [21] about the appropriate alkalisation treatment at 5%. Further additions of excessive alkalisation concentrations can eliminate some of the natural composite fibres' lignin, decreasing the composites' mechanical qualities.

4. CONCLUSION

These are the findings of this study:

1. Adding coffee husk waste can decrease polypropylene composites' tensile and flexural strength. The addition of 20%wt coffee husk waste with 5% KOH alkalisation to the polypropylene composite produced the maximum tensile and flexural strength values of 5.65 MPa and 28.72 MPa, respectively.
2. Variation in the amount of KOH alkalisation treatment on coffee husk waste diminishes the tensile strength of polypropylene composites. With the addition of 20%wt of coffee husk waste, the treatment without alkalisation of 0% KOH on coffee husk waste produced the maximum tensile strength of 13.30 MPa. The impact strength of polypropylene composites is enhanced by varying the proportion of KOH alkalisation treatment applied to coffee husk waste. With the addition of 20% wt of coffee husk waste, the alkalisation treatment with 11% KOH produced the highest impact strength value of 4.62 kJ/m^2 for coffee husk waste. Variation in the percentage of coffee husk waste alkalised with KOH diminishes its flexural strength. With the addition of 20%wt coffee husk waste, the alkalisation treatment with 5% KOH produced the most excellent flexural strength value of 28.72 MPa.

Blending polypropylene with alkalised coffee skin waste is recommended to use a compounder first. The homogeneous composite pellets will be obtained in the composite moulding process using the Manual Forming Machine.

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