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Duroboard: Development of Plastic Composite Board Using Durian (*Durio zibethinus cv. native*) and Low-Density Polyethylene (LDPE) Waste

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Abstract—*This study investigated the development of a plastic composite board utilizing durian peels, durian seeds, and low-density polyethylene (LDPE) plastic waste. The physical, mechanical, and thermal properties of the particle boards were evaluated using three ratios Ratio 1; 1:1 (Durian Peels and LDPE), Ratio 2; 1:1 (Durian Seeds and LDPE), and Ratio 3; 1:1:2 (Durian Seeds, Durian Peels and LDPE), focusing on varying material ratios to identify the optimal composition. Key tests included density, thickness swelling, water absorption, flexural strength, tensile strength, and thermal resistance. Physical testing analysis indicated maximum density of 831.9 kg/m³ in Ratio 3, while water absorption was minimum in Ratio 2 with 0.011%. ANOVA analysis indicated no significant differences in density between groups ($p = 0.6034 > 0.05$). Thickness swelling was typical, with significant differences within 22 hours of soaking ($p = 0.01105 > 0.05$). Mechanical testing analysis indicated Ratio 3 had maximum flexural strength of 1.52 MPa, while maximum tensile strength was in Ratio 2 of 0.0116 MPa. ANOVA confirmed significant differences in flexural strength ($p = 9.018e-10 < 0.05$) and tensile strength ($p = 0.00001066 < 0.05$). Thermal testing analysis indicated all samples burned without any plastic dripping, while Ratio 3 had maximum melting resistance. Breakage analysis indicated minimum failure in Ratio 3. The research concluded that Ratio 3 (1:1:2 of durian peels, seeds, and LDPE) had the best combined characteristics. Hydraulic compression and optimization of ratio for improvement is recommended to improve commercial viability. These results indicate the potential of wastage composites of agricultural and plastic as green alternatives to traditional particleboard. The researcher recommended using hydraulic compression to achieve the best quality of the product. Testing must be performed in a testing laboratory, additional research on other possible proportions to maximize its properties, conducting more research using different waste materials for particle board, and lessen the use of engine oil and make use of finely crushed durian peels.*

I. Introduction

The Philippines is a tropical paradise blessed with year-round sunshine and warm temperatures; the country offers a captivating blend of stunning beaches, lush rainforests, and vibrant culture. Its tropical climate, characterized by distinct wet and dry seasons, has shaped its unique biodiversity and agriculture. This perfect weather has transformed the country into a fertile ground for many exotic and delectable fruits. From the sweet and juicy mangoes to the tangy and refreshing calamansi, the Philippine fruit bounty is a testament to the country's tropical paradise. One of those exotic and delectable fruits is the Durian.

Often hailed as the "King of Fruits," the durian is a tropical treasure that has captivated taste buds and ignited passionate debates for centuries. Native to Southeast Asia, this iconic fruit is renowned for its distinctive appearance, potent aroma, and undeniably unique flavor profile (Thorogood et al., 2022). With its thorny exterior and creamy, custard-like flesh, the durian is an exceptional culinary experience that promises to intrigue and delight. On the contrary, these delectable fruits can raise concerns about solid waste management. Approximately 80% of durian is non consumable, respectively.

Changing our attention to another important area of waste management: plastics. Low-density polyethylene (LDPE) is a thermoplastic that is frequently utilized for residential, business, and industrial uses. It is very similar to HDPE plastic, but the key differences are that LDPE tends to be thinner, softer, less intense, and more flexible than HDPE. But the good news is that recycling LDPE is not only a possibility but a key to a more sustainable world (Business Waste, 2020).

In recent years, the use of recycled materials in composite board production has gained significant attention due to growing environmental concerns. Polymeric composite materials must have high mechanical and physical properties, biodegradability, waterproof and fireproof properties, and low cost to compete with wood-based materials (Tasdemir et al., 2019). Many manufacturers are incorporating sustainable practices to reduce their ecological footprint.

This research aims to reduce waste, conserve resources, and inspire hope for a more sustainable future by harnessing the potential of these otherwise discarded materials. Creating a high-performance, eco-friendly composite from these materials aligns with the growing emphasis on circular economic principles and sustainable manufacturing, offering a promising solution to our waste management challenges.

Integrating durian waste as reinforcing fibers offers a unique opportunity to value abundant agricultural byproducts. Incorporating recycled LDPE as a polymeric matrix provides flexibility, durability, and water resistance. Meanwhile, waste oil is a potential plasticizer and bonding agent, enhancing the composite's processability and mechanical properties.

This study will delve into the material characterization, processing optimization, and performance evaluation of the developed plastic composite board. The findings will

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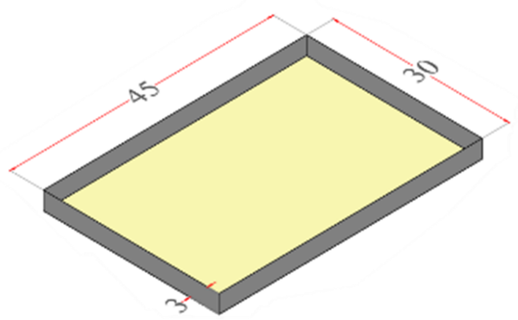
contribute to advancing sustainable composite materials and provide a potential blueprint for effectively managing agricultural and industrial waste streams.

II. METHODOLOGY

This methodology section outlines the systematic procedures employed to gather, analyze, and interpret data, ensuring the validity of the research outcome. Detailed explanations of the processes undertaken are provided, offering transparency in the methods applied and their justification within the context of the study.

A. Modification of Molder

The mold used in the production of particle board is a mold with the dimensions of 45 cm x 30 cm x 1.27 cm (L x W x T) shown in Figure 1.



(1)

B. Collection of Raw Materials

LDPE was collected at Salaan Sanitary Landfill and waste oil was collected near the researcher's residence. Durian waste was collected from fruit stands at Pasonanca, Zamboanga City.

The materials used for this study are recycled plastic waste LDPE with a resin code number 4, durian wastes (peel and seed), and waste oil. The plastic composite board production uses the following equipment: digital weighing scale, G-clamps, digital calliper, stainless steel container, 45 cm x 30 cm x 0.5 cm molder, and basin.

C. Preparation of Raw Materials

Durian peels and seeds were cleaned thoroughly to remove dirt and sundried for at least 24 hours. They were then oven-dried at 150° for 30 minutes to remove moisture. After oven drying, the waste is powdered and mixed with waste oil. The waste oil is poured slowly until the mixture is uniformly distributed. The sample mixtures are now placed on a screen to drain excess oil until all excess oil has been removed.

The collected plastic was cleaned and dried thoroughly with distilled water to remove unwanted dirt and lessen impurities in the sample mixture, and it was solar-dried after cleaning. After drying, the plastic was cut into smaller pieces.

D. Production Process

The LDPE cut pieces were proportioned to each mixture and melted in a stainless container at 150º C using a flame gun. Once melted, it was mixed for ten (10) minutes. While mixing continuously, the required mass of treated dried durian waste was added portion by portion. After the mixing and while in a molten state, the mixture was poured into the mold measuring 45 cm x 30 cm x 1.2 cm (length x width x thickness) and then covered. After drying, the plastic composite board was removed from the mold and allowed to cool and cure through air drying for 24 hours. The last step was to cut or trim the product to its desired size. This process was repeated for each mixture's properties.

E. Testing

Based on the different formulated proportions, 10 plastic composite board samples (10 cm x 5 cm x 1.27 cm) were used for each parameter for physical tests such as density, thickness swelling, and water absorption tests. For the mechanical test, 10 plastic composite board samples (10 cm x 5 cm x 1.27 cm) were used for the flexural strength test, 10 plastic composite board samples (10 cm x 5 cm x 1.27 cm) for the tensile strength test, and 10 particle board samples (10 cm x 5 cm x 1.27 cm) for breakage test, and for the thermal test, ten (10) plastic composite board samples (10 cm x 5 cm x 1.27 cm) were used for the flammability test, 10 plastic composite samples (10 cm x 5 cm x 1.27 cm) for the heat test. There were 80 samples used in total for material testing.

Physical testing for this study included density. Density test was carried out using six (6) particle board samples per proportion measuring 10 cm x 5 cm x 1.27 cm (L x W x T). The samples were weighed using a digital weighing scale and the size of the sample was measured using a digital caliper. Tests for thickness swelling and water absorption was performed on ten 10 cm x 5 cm x 1.27 cm boards with all four sides smoothly and squarely trimmed according to the ASTM D1037 guidelines.

Mechanical testing for this study includes tensile strength, flexural strength, and breakage of product. The flexural strength of the particle board was carried out using ten (10) particle board samples per proportion measuring 10 cm x 5 cm x 1.27 cm (L x W x T). To determine the modulus of rupture of the particle board, test samples underwent a three-point-bending test according to EN 310, using a modified testing from ASTM D4761-19. The tensile strength of the particle board was carried out using ten (10) particle board sample per proportion measuring 10 cm x 5 cm x 1.27 cm (L x W x T). To measure the ability of the particle board to withstand pulling or stretching and the maximum load that can be applied to the material before it ruptures, a modified testing from ASTM D1037 was conducted for this parameter. And the breakage was carried out using ten (10) particle board samples per proportion measuring 10 cm x 5 cm x 1.27 cm (L x W x T). To determine the durability of the particle board, the test samples underwent a falling ball test adapted from ASTM 1037.

Since the plastic composite board product contains plastic and a small amount of waste oil, flammability and heat tests was conducted on 10 samples per proportion, each sample measured 10 cm x 5 cm x 1.27 cm (L x W x T) to evaluate the behavior of materials in response to exposure to fire or high-temperature conditions. For the flame test, each sample was placed horizontally in the burn chamber, and controlled fire was placed under the sample for 60 seconds, various aspects of the material's behavior during the test were recorded including its burned mark and plastic drips. The process was adopted from ASTM E69. For the heat test, ten (10) samples from each ratio were placed inside the oven at a temperature of 170 degrees Celsius for 10 minutes and recorded whether the samples will melt or not.

The collected data were analyzed, tabulated, and interpreted using descriptive and inferential statistical methods. Data normality and homogeneity were assessed using Levene's Test to determine whether parametric or non-parametric test will be applicable. For normally distributed data, an ANOVA (Analysis of Variance) test was used to determine if there are significant differences in the means and standard deviations of the groups.

F. Formulas

a. The density of the sample was calculated using

$$\rho = \frac{m}{v} \tag{2}$$

Where:

ρ= Density of the sample (g/cm3)
m= Mass of the sample (g)
v= Volume of the sample (cm3)

b. The width, length, and thickness of the specimen measured to an accuracy of 60.3 % to compute the volume of the specimen. The thickness was measured at four points midway along each side 1 in. (25 mm) in from the edge of the specimen and the average of these four measurements were used for the thickness swelling determination.

$$PT= \frac{T_0 - T_1}{T_1} x\ 100\% \tag{3}$$

Where:

PT= Thickness swelling of the sample (%)
T1= Initial thickness of the sample
T0= Swelling thickness of the sample

c. The value of thickness swelling was expressed in percentage and was calculated using the equation

$$WA= \frac{W_W - W_d}{W_d} x\ 100\% \tag{4}$$

Where:

WA= Water Absorption of the sample (%)
Wd= Initial dry weight of the sample (g)
Ww= Wet weight of the sample (g)

d. A load was placed in the center profile, then the bending load was recorded. The flexural strength of the sample was calculated using

$$FS= \frac{3FL}{2WD^2} \tag{5}$$

Where:

FS = Flexural Strength of the sample (MPa)
F = Maximum force (N)
L = Length (m)
W = Width (m)
D = Depth (m2)

e. To measure the ability of the particle board to withstand pulling or stretching and the maximum load that can be applied to the material before it ruptures, a modified testing was conducted for this parameter. A clamp was attached to both ends of the sample and was placed horizontally, the clamp at the lower end had a container attached to it as the load (sand) was gradually loaded until the sample breaks apart, the breaking load is recorded.

$$TS= \frac{F}{A} \tag{6}$$

Where:

TS = Tensile Strength of the sample (MPa)
F = Maximum force (N)
A = Cross-sectional area (m2)

f. Thermal Testing

Since the plastic composite board product contains plastic and a small amount of waste oil, flammability and heat tests was conducted on 10 samples per proportion, each sample measured 10 cm x 5 cm x 1.27 cm (L x W x T) to evaluate the behavior of materials in response to exposure to fire or high-temperature conditions. For the flame test, each sample was placed horizontally in the burn chamber, and controlled fire was placed under the sample for 60 seconds, various aspects of the material's behavior during the test were recorded including its burned mark and plastic drips. The process was adopted from ASTM E69. For the heat test, ten (10) samples from each ratio were placed inside the oven at a temperature of 170 degrees Celsius for 10 minutes and recorded whether the samples will melt or not.

The collected data were analyzed, tabulated, and interpreted using descriptive and inferential statistical methods. Data normality and homogeneity were assessed using Levene's Test to determine whether parametric or non-parametric test will be applicable. For normally distributed data, an ANOVA (Analysis of Variance) test was used to determine if there are significant differences in the means and standard deviations of the groups. However, if the data were not normally distributed, the Kruskal-Wallis' test (a nonparametric alternative to ANOVA) was used to compare the medians of the groups with a significance level of $\alpha = 0.05$. For the statistical computations required in this analysis, we will use the online statistical software platform, Statistics Kingdom.

III. Results and Discussion

This chapter includes a full presentation and discussion of the results of this study. The results provide a comprehensive analysis of the findings derived from the experiments conducted and observations.

Density Test

Based on the experiment, the control, Ratio 1, Ratio 2, and Ratio 3 weighed roughly the same, Table 4.1 shows the mass (g) and volume (cm3) of each sample and Table 4.2 shows the result of the experiment on density (g/cm3) of each ratio.

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The table shows that Ratio 2 has the highest mean mass and Ratio 1 has the highest mean volume in all ratios. Ratio 1 Sample No. 4, has the highest mass and Ratio 2 Sample No. 10, has the highest volume in all samples.

Mass (g) and Volume (cm^3) of the Composite Board Sample Ratios and Control

Sample No.	Control		Ratio 1		Ratio 2		Ratio 3	
	Mass (g)	**Volume (cm^3)**	**Mass (g)**	**Volume (cm^3)**	**Mass (g)**	**Volume (cm^3)**	**Mass (g)**	**Volume (cm^3)**
1	76	75.99715	77	85.69622	70	72.47	57	66.06522
2	43	55.88154	70	76.18715	65	72.72	71	75.11978
3	67	74.56914	67	70.47578	58	70.30	73	88.28663
4	60	70.38662	82	94.21536	76	85.53	73	84.82584
5	63	72.93257	75	81.48665	67	65.07	76	81.8617
6	47	75.332	71	79.68095	64	77.7	65	76.23123
7	70	77.18099	71	82.2528	79	85.49	72	75.70644
8	67	74.56914	76	90.465	75	81.144	62	80.07502
9	67	75.69409	72	80.25287	76	83.41	64	73.3422
10	63	100.9895	66	68.03865	46	98.92	47	64.15902
Mean	**65.6**	**75.37**	**72.8**	**81.88**	**73.6**	**79.28**	**71.2**	**76.07**
Standard Deviation	**12.1**	**10.98**	**11.31**	**8.63**	**5.76**	**9.77**	**12.25**	**6.90**

ANOVA Results for Density (g/cm^3)

Source	DF	Sum of Square	Mean Square	F Statistics	P-Value
Groups (between groups)	2	0.01031	0.005153	0.5147	0.6034
Error (within groups)	27	0.2703	0.01001		
Total	29	0.2806	0.009677		

The density of a material significantly influences how well it maintains its shape and size when exposed to changes in moisture and temperature (Servano, 2024). Materials with higher density generally exhibit greater dimensional stability, making them more suitable for applications where maintaining the integrity of the structure is crucial, such as furniture or building components.

In this study, the control did not display any signs of swelling. Meanwhile, Ratios 1, 2, and 3 have shown minimal swelling, suggesting that the components that made up the different ratios prevented or inhibited the board from swelling. The ratio's swelling thickness was determined by measuring four randomly selected points and calculating their average, which was recorded as the ratio's swelling thickness. Table 4.4 shows the thickness swelling (mm) of each sample and Table 4.5 shows the result of thickness swelling percentage.

Among the four ratios, the control used did not swell like the rest of the group as the material used has more plastic percentage than the wood flour used (Nuryawan et al., 2020). According to the standard reference SNI 03-2105-2006 for particleboard, the thickness swelling should be less than 12% after immersing into the water. The longer the groups were immersed, the more the samples and the composition of the samples were different from each other. The composition of ratio 3 which is composed of durian peels and seeds mixed with spent engine oil with LDPE plastic being the highest weight percentage of the composition. Additionally, spent engine oil added to its water resistance properties (Kairytė et al., 2020).

Thickness Swelling in percentage

Sample No.	Control		Ratio 1		Ratio 2		Ratio 3	
	10mins	22hrs	10mins	22hrs	10mins	22hrs	10mins	22h
1	0	0	0	0	0.0076	0.015	0.0074	0.00
2	0	0	0.0064	0.0128	0.0078	0.016	0	0.00
3	0	0	0.0071	0.0142	0.0076	0.015	0.0056	0.00
4	0	0	0.0054	0.0108	0.0057	0.011	0.0060	0.00
5	0	0	0.0061	0.0122	0.0081	0.016	0.0062	0.01
6	0	0	0.0063	0.0126	0.0062	0.012	0	0.00
7	0	0	0.0062	0.0124	0.0059	0.012	0.0067	0.00
8	0	0	0.0054	0.0107	0.0061	0.0122	0	0
9	0	0	0.0062	0.0123	0.0058	0.0117	0.0131	0.01
10	0	0	0.0074	0.0147	0.0054	0.0109	0.0075	0.01
Mean	**0**	**0**	**0.0056**	**0.0113**	**0.0066**	**0.0132**	**0.0052**	**0.00**
Standard Deviation	**0**	**0**	**0.0020**	**0.0041**	**0.0010**	**0.0019**	**0.0042**	**0.00**

Water Absorption in percentage

Sample No.	Control		Ratio 1		Ratio 2		Ratio 3	
	10mins	22hrs	10mins	22hrs	10mins	22hrs	10mins	22hr
1	0	0	0	0	0	0	0.0175	0.017
2	0	0	0.0142	0.0285	0.0153	0.0153	0	0.014
3	0	0	0	0	0.0172	0.0172	0.0273	0.027
4	0	0	0.0121	0.0243	0	0	0.0136	0.013
5	0	0	0	0	0	0	0.0131	0.026
6	0	0	0	0	0.0156	0.0156	0	0.015
7	0	0	0	0	0	0	0.0138	0.013
8	0	0	0.0131	0.0263	0.0133	0.0133	0	0
9	0	0	0.0138	0.0277	0.0263	0.0263	0.0312	0.031
10	0	0	0	0	0.0217	0.0217	0	0.021
Mean	**0**	**0**	**0.0053**	**0.0107**	**0.0109**	**0.0109**	**0.0116**	**0.018**
Standard Deviation	**0**	**0**	**0.0069**	**0.0138**	**0.0101**	**0.0101**	**0.0116**	**0.008**

Water Absorption Test

The results showed that the ratio's water absorption was determined by weighing each sample and calculating their average, which was recorded as the ratio's wet weight. Table 4.8 shows the mass (g) of each sample and Table 4.9 show the result of water absorption percentage.

The results suggest that the groups exhibit no profound differences in swelling over a short time (10 minutes) due to the short amount of period the samples were immersed. However, over a longer duration (22 hours), the differences become statistically significant, likely indicating that the factor being analyzed has a delayed effect on thickness swelling. This is excess spent engine oil washed out the longer the samples were immersed in water, as observed when the testing was on going.

Flexural Strength Test

The flexural strength test evaluated how well the ratio could withstand bending forces without breaking or deforming significantly. In the experiment, it was observed that the control has a high breaking load of 1290.9 compared to ratios 1, 2, and 3. This indicates that the control had the higher ability resist deformation under load. The breaking load of each sample was shown in Table 4.12 and the result of flexural strength (MPa).

Flexural Strength (MPa)

Sample No.	Control (MPa)	Ratio 1 (MPa)	Ratio 2 (MPa)	Ratio 3 (MPa)
1	1035	0.341046	0.553141	1.861637
2	1363	0.456157	0.579568	1.084873
3	1515	0.558126	0.574291	1.128332
4	1210	0.321709	0.288789	1.110512
5	1057	0.427875	0.580343	1.557307
6	1617	0.413604	0.41329	1.704783
7	1156	0.35134	0.370594	1.670386
8	1365	0.362759	0.263569	1.012479
9	1345	0.516225	0.377565	1.691021
10	1246	0.837333	0.264752	2.394459
Mean	**1290.9**	**0.458618**	**0.42659**	**1.521579**
Standard Deviation	**187.7146**	**0.153799**	**0.134307**	**0.439288**

Throughout all samples, the Control consistently shows the highest flexural strength for each sample compared to the three (3) ratios. For Ratio 3, sample 6 demonstrates a relatively high flexural strength of 1.704783 MPa, while sample 8 has a lower value of 1.041279 MPa. For Ratio 1 and Ratio 2, the flexural strength values are generally closer to their respective means, reflecting smaller variability compared to the control and Ratio 3.

Tensile Strength Test

The tensile strength test involved determining the maximum load that the ratio could withstand. In the study, it was observed that the control has a high tensile strength compared to Ratios 1, 2, and 3. This indicates that the control had the higher ability of a material to withstand stretching or pulling forces without breaking or deforming.

Tensile Strength (MPa)

Sample No.	Control (MPa)	Ratio 1 (MPa)	Ratio 2 (MPa)	Ratio 3 (MPa)
1	12.81	0.01001	0.011719	0.010081
2	12.45	0.01005	0.011491	0.010091
3	12.58	0.00996	0.012426	0.01001
4	13.82	0.00996	0.011755	0.009843
5	16.25	0.00998	0.010529	0.009921
6	19.35	0.009891	0.013364	0.010081
7	16.46	0.009921	0.011333	0.00997
8	17.64	0.01	0.013158	0.00996
9	13.45	0.00993	0.011616	0.00996
10	12.64	0.009901	0.009136	0.010373
Mean	**14.745**	**0.009960393**	**0.011652762**	**0.010028912**
Standard Deviation	**2.482281**	**5.08627E-05**	**0.001226141**	**0.000144385**

The assumptions for normality and homogeneity were checked using Levene's test. One (1) group doesn't distribute normally which is the control with 0.09038 normality and homogeneity of variances which explained 57.2% of the deviation from the average.

The F-statistics of 18.0255 indicates the ratio of variance between groups to variance within groups, showing a significant difference in tensile strength across the groups. The p-value of 0.00001066 is well below the typical significance threshold of 0.05, confirming that the differences observed are statistically significant and unlikely to have occurred by chance. The results indicate that the tensile strength varies significantly between the groups, with the observed differences being statistically significant.

Breakage Test

In drop test the ability of particle board to withstand sudden impacts or collisions is assessed under controlled conditions. The result showed that a few from each different ratios shown breakage from the testing, mainly from Ratio 3 and the rest of the samples were able to withstand the impact.

Flammability Test

In the flammability test, the materials' susceptibility to ignition and combustion was evaluated under controlled conditions. Based on the result, all sample have burned to an extent of having wrinkles and across all samples and ratios, the result is consistently B-NPD (Burned - No Plastic Dripped). It was observed that some peels in ratio 1 were burned. Ratio 3 shown the best results as there were no visible burned peels as shown in Figure 4.6. This indicates that for every sample, regardless of the ratio type, the material burned but no plastic dripping was observed during the test.

Breakage Test

Sample No.	Control (2m high)	Ratio 1 (2m high)	Ratio 2 (2m high)	Ratio 3 (2m high)
1	N	B	N	N
2	N	N	B	N
3	N	B	N	B
4	N	N	N	N
5	N	B	B	N
6	N	N	N	B
7	N	B	N	N
8	N	N	B	N
9	N	N	N	B
10	N	B	N	N

Where:
N – No Changes
B – Broke

Flammability Test

Sample No.	Control (2m high)	Ratio 1 (2m high)	Ratio 2 (2m high)	Ratio 3 (2m high)
1	B-NPD	B-NPD	B-NPD	B-NPD
2	B-NPD	B-NPD	B-NPD	B-NPD
3	B-NPD	B-NPD	B-NPD	B-NPD
4	B-NPD	B-NPD	B-NPD	B-NPD
5	B-NPD	B-NPD	B-NPD	B-NPD
6	B-NPD	B-NPD	B-NPD	B-NPD
7	B-NPD	B-NPD	B-NPD	B-NPD
8	B-NPD	B-NPD	B-NPD	B-NPD
9	B-NPD	B-NPD	B-NPD	B-NPD
10	B-NPD	B-NPD	B-NPD	B-NPD

Where:
B – Burned
NPD – No Plastic Dripped
PD – Plastic Dripped

Heat Test

The heat test involves determining the materials' behavior when exposed to elevated temperatures. The results show that control did not react to high heat, while ratios 1, 2, and 3 did.

Based on the result, it was observed that there was no change to the control, while for Ratio 1 was melted throughout the edges, during the test the peels catch on fire thus making the sample melt faster than the other groups, this is due to the high fiber content of durian peels in this mixture (Chun et al., 2018). Ratio 2 samples showed melt on the edge of the board as the wt % of plastic is more than the wt% of the durian seeds. Ratio 3 showed changes on the edge of sample. The result of heat test was shown in Table 4.20.

The flammability test results suggest that the ratios altered the material's properties, causing it to melt when exposed to the test conditions, whereas the untreated material (Control) remained unchanged. This highlights a potential trade-off in the ratios, where the material's resistance to melting was compromised.

Heat Test

Sample No.	Control (2m high)	Ratio 1 (2m high)	Ratio 2 (2m high)	Ratio 3 (2m high)
1	NC	M	M	M
2	NC	M	M	M
3	NC	M	M	M
4	NC	M	M	M
5	NC	M	M	M
6	NC	M	M	M
7	NC	M	M	M
8	NC	M	M	M
9	NC	M	M	M
10	NC	M	M	M

Where:
NC – No Changes
M – Melted

The summary result of the physical and mechanical properties of the particleboard was shown in Table with prescribed values as IS 3087.

Physical and Mechanical Properties Comparison

Properties	Control	Ratio 1	Ratio 2	Ratio 3	Prescribed Values as IS 3087
Density (kg/m^3)	940	759.6465	825.3427	831.9469	500-900
Thickness Swelling (%)	0	0.01130	0.01327	0.007944	Maximum 12%
Water Absorption (%)	0	0.010706	0.010964	0.018084	Maximum 40%
Flexural Strength (MPa)	1290.9	0.458618	0.42659	1.521579	9-11
Tensile Strength (MPa)	14.745	0.009960393	0.011652762	0.010028912	Minimum 0.8

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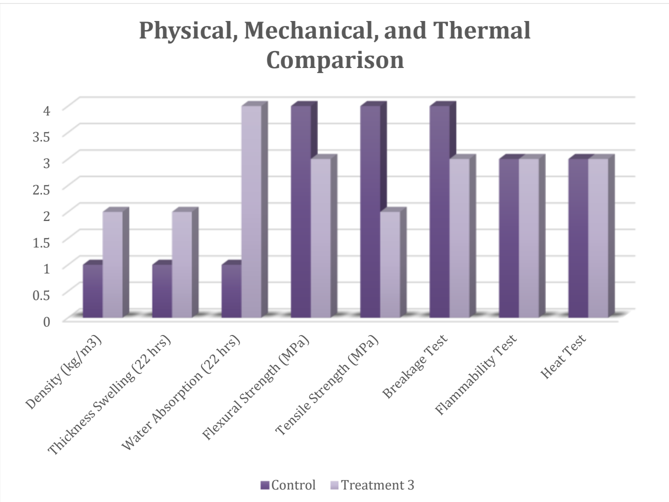
To evaluate the best physical, mechanical, and thermal properties among Control, Ratio 1, Ratio 2, and Ratio 3, the result was ranked according to their value. Where 4-Highly Satisfactory, 3- Satisfactory, 2-Moderately Satisfactory, and 1-Unsatisfactory. Table 4.22 shows the ranking method of the value of each ratio.

Ranking of Physical, Mechanical, and Thermal Properties

Properties	Control	Ratio 1	Ratio 2	Ratio 3
Physical Properties				
Density (kg/m^3)	1	4	3	2
Thickness Swelling (%)	1	3	4	2
Water Absorption (%)	1	2	3	4
Mechanical Properties				
Flexural Strength (MPa)	4	2	1	3
Tensile Strength (MPa)	4	1	3	2
Breakage Test	4	1	2	3
Thermal Properties				
Flammability Test	3	3	3	3
Heat Test	3	1	2	3
Total Score:	**21**	**17**	**21**	**22**

Where: **4**-Highly Satisfactory
3- Satisfactory
2-Moderately Satisfactory
1- Unsatisfactory

Physical, Mechanical, and Thermal Comparison of Control with Ratio 3



Based on the evaluation of the properties, the ratio that has the best Physical, Mechanical, and Thermal property is Ratio 3 with 1:1:2 ratio of Durian peels, seeds and LDPE plastic.

Comparing the physical, mechanical, and thermal properties of commercial particle board with particle board made with plastic polypropylene, rice husk, and spent engine oil is shown.

IV. CONCLUSION AND RECOMMENDATIONS

Conclusion

Particle board made from durian peels, durian seeds, LDPE plastics and spent engine oil demonstrates varying physical, mechanical, and thermal properties.

1. Physical Properties

In examining the physical test, the results showed that Ratio 3 has the highest density recorded with 831.9 kg/m3, showing the p = 0.6034 for the groups. Thickness swelling results showed no significant difference as the ratios had 0-2% swelling increase with a p value of 0.5174 and 0.01105 for 10 minutes and 22 hours immersion, respectively. And the lowest water absorption recorded are from Ratio 2 with 0.011% with a p value of 0.2989 and 0.2631 for 10 minutes and 22 hours immersion, respectively.

2. Mechanical Properties

In examining the mechanical test, the results showed that Ratio 2 has the highest flexural and tensile strength recorded with 1.68 MPa, with a mean of 0.42659 and standard deviation of 0.13407 and 0.09 MPa with a mean of 0.01165 and standard deviation of 0.00122, respectively. The ANOVA results disclosed that there are significant differences in flexural and tensile strength among the groups with high F-statistic value of 49.6431 and extremely low p-value of 9.018e-10 for flexural strength and a F-statistic value of 18.0255 and low p-value of 0.00001066 for tensile strength. And the ratio with a minimal breakage is Ratio 2 and 3 with 3 broken samples.

3. Thermal Properties

In examining the thermal test, the results showed that all ratios showed signs of burning with no plastic dripping. And Ratio 3 has the highest melting point from the group. The results suggest that none of the ratios had an observable effect on preventing the burning of the material.

4. Mixing Ratio that provides the best Property

After the experimentation. It is concluded that Ratio 3 (1:1:2 Durian Seeds, Durian Peels and LDPE) is feasible as it has the best physical, mechanical and thermal properties among the four ratios, having the highest score in the ranking or each ratio.

5. Feasible Plastic Composite Board Ratio

Ratio 3 made with durian peels and seeds and LDPE plastic with spent engine oil particle board exhibits the best mechanical and thermal properties.

Recommendation

Particle board made from durian peels, durian seeds, and LDPE plastic has potential, as an alternative board but requires additional enhancements before it can be commercialized. The following are suggested:

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1. Use hydraulic compression to achieve the best quality of the product.
2. Test must be performed in a testing laboratory.
3. Additional research on other possible proportions to maximize its properties.
4. Conduct more research using different waste materials for particle board; and
5. Lessen the use of engine oil and make use of finely crushed durian peels.

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