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Physical Retting of Apple (*Malus Domestica*) Peels, Dehydrated Jackfruit (*Artocarpus Heterophyllus*) Rinds, and Mango (*Mangifera Indica*) Peels for Alternative Multipurpose Paper Component

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A B S T R A C T

This study was conducted to determine the potential of apple (Malus domestica) peels, dehydrated jackfruit (Artocarpus heterophyllus) rinds, and mango (Mangifera indica) peels physically retted for alternative multipurpose paper component. This study used Complete Randomized Design with 4 treatments for each, with commercial multipurpose paper (CMP) as the control. There are 4 replicates for each treatment and 3 samples for each replicate, amounting to 12 samples per treatment. Physically retted M. domestica peels (AP), dehydrated A. heterophyllus rinds (JFR), and M. indica peels (MP), were subjected to pulp-making process and paper processing through mould and deckle method. It was found that the durability in terms of time (seconds) it takes for the papers made from JFR T3 (200g JFR + 100g cornstarch) and MP T1 (pure MP) to break down into pieces when submerged in water is comparably similar with CMP (α=0.05). It is concluded that based on comparative durability to CMP, JFR and MP can potentially be used as a component in making multipurpose paper. Recommendations such as determining the effects of the fibers physically retted from JFR and MP on the quality of the multipurpose papers produced is encouraged.

Keywords: Physical retting, Multipurpose paper, Completely Randomized Design, apple (*Malus domestica*) peels, Dehydrated jackfruit (*Artocarpus heterophyllus*) rinds, Mango (*Mangifera indica*) peels, Fiber extraction

Introduction

Paper wastage facts show that 85 million tons of paper waste are created each year and nearly 4 billion trees worldwide are cut down each year for paper. This is about 680 pounds of paper waste per person. Paper also accounts for around 40% of total waste at landfills (Xodo Sign, 2018). In many businesses and sectors, paper waste is a serious issue, Due to printing errors, unwanted mail, billing errors, and packaging. Deforestation is the conversion of forest to an alternative permanent non-forested land use such as agriculture, grazing or urban development (van Kooten & Bulte, 2000). Deforestation is primarily a concern for the developing countries of the tropics (Brown & Pearce, 2023) as it is shrinking areas of the tropical forests (Barraclough & Ghimire, 2000) causing loss of biodiversity and enhancing the greenhouse effect (Angelsen, 1999). It is the consumption of vast quantities of energy and water, as well as difficulties with air pollution and waste, are some of the negative environmental repercussions of paper manufacture. Wood products, including paper, contributes for approximately 10% of overall deforestation (Union of Concerned Scientists, 2016). Paper is a thin sheet material produced by mechanically or chemically processing cellulose fibers. Cellulose is the primary ingredient of paper, cardboard, and textiles; it is the primary component of plant cell walls, cellulose, keeps plants rigid and erect (Klemm, Heublein, Fink, & Bohn, 2005). Pulp is created by turning several sources of cellulose fibers into pulp. To make paper, pulp is blended with water and flattens, dries, and cuts the pulp into sheets and rolls. The main benefit of recycled paper is that it's exceptionally strong, which is a result of its increased sulfur and decreased lignin content. This stronger form of paper has a lot more durability than alternative materials in most planes and is a lot more resistant to piercing than paper (Forbes, 2023). Multipurpose paper is used for numerous industrial and commercial applications due to its strength. The substance is utilized in packaging processes for void filling, bundling, individual item wrapping, and packing. Multipurpose paper can also be used to hold layers of palatable products together. In addition to these wide-ranging uses, Multipurpose paper has other applications as well, including skid and pallet covering, paint masking, fiberglass operations, interior painting, and floor covering (SSI Packaging Group Inc, 2022). The lack of water resistance in paper-based packaging is a common drawback. Apple (*Malus domestica*) or apple pomace contain a great amount of cellulose and cellulose fiber are the ones that we use on making paper and such. It accounts for about 25% of the original fruit mass and typically contains 66.4%–78.2% moisture 26.4% dry matter, 4.0% proteins, 9.5%–22.0% carbohydrates, 3.6% sugars, 6.8% cellulose, 0.38% ash, 0.42% acid and calcium, 8.7 mg/100 g of wet apple pomace (Shalini & Gupta, 2010). The Jackfruit (*Artocarpus heterophyllus*) is commonly found in the countries of south and south-east Asia wherein many individuals use this fruit in cuisines and medicine (Swami, Thakor, Haldankar, & Kalse, 2012). The *A. heterophyllus* rind is usually thrown away because many believe that it is not edible. But to make it edible it must be prepped and preserved which is hassle. The ripe *A. heterophyllus* has 59% peel, which is a rich source of pectin in the form of calcium pectate, which is made up of 27.75% cellulose, 7.52% pectin, 6.27% protein, and 4% starch (Rahman, Nahar, Mian, & Mosihuzzaman, 1999). The *A. heterophyllus* rind is rich in cellulose which makes a great alternative material in this research. Mango (*Mangifera indica*) is an edible stone fruit produced by the tropical tree which is believed to have originated from the region between north-western Myanmar, Bangladesh, and north-eastern India. *M. indica* is processed to a maximum extent, thereby producing a high quantity of solid and liquid wastes: approximately 30% to 50% of the total fruit as waste, of which 15% to 25% is peel waste and 15% to 25% is kernel (Madhukara, Nand, Raju, & Srilatha, 1993); (Maini & Sethi, 2000). Utilization of the *M. indica* peels waste is both a necessity. Approximately 0.6 to 0.8 million tons of *M. indica* peel is generated annually in India. This waste is either used as cattle feed or dumped in open areas, where it adds to environmental pollution. These, among other things stated, prompted the researchers to conduct this study. This study aims to determine the potential of apple (*Malus domestica*) peels, dehydrated jackfruit (*Artocarpus heterophyllus*) rinds, and mango (*Mangifera indica*) peels physically retted for alternative multipurpose paper component. Specifically, this study aims to determine the mean±standard deviation durability in terms of time (seconds) it take for the papers made from apple (*Malus domestica*) peels, dehydrated jackfruit (*Artocarpus heterophyllus*) rinds, and mango (*Mangifera indica*) peels to break down into pieces; and to determine the significant difference of the durability in terms of time (seconds) it take for the papers made from apple (*Malus domestica*) peels, dehydrated jackfruit (*Artocarpus heterophyllus*) rinds, and mango (*Mangifera indica*) peels to break down into pieces when compared to a commercial multipurpose paper.

The scope of the study is the physical retting of apple (*Malus domestica*) peels, dehydrated jackfruit (*Artocarpus heterophyllus*) rinds, and mango (*Mangifera indica*) peels as an alternative multipurpose paper component. It is delimited to the determination of the durability of the multipurpose paper added with apple (*Malus domestica*) peels, dehydrated jackfruit (*Artocarpus heterophyllus*) rinds, and mango (*Mangifera indica*) peels physically retted component in terms of time (seconds) it takes for the papers to break down into pieces. Other variables such as components' ages, strength, flexibility, among other variables related to multipurpose paper quality was not determined in this study. Significantly, In the field of physical and material science, the most probable contribution of the study is to make a more sustainable multipurpose paper which can be used diversely, such as crafts, stationery, packaging, and industrial uses, as it has greater durability than ordinary paper. It will benefit society in view of the fact that the materials used are more sustainable and eco-friendlier compared to commercial multipurpose paper. Furthermore, it will also help lessen the pollution for the reason that no preservatives and chemicals were used in this study. Additionally, this research will benefit those who are in the craft industry, it will help in businesses and people who use multipurpose paper for their products and people who uses paper for a variety of reasons. The results of this study will help future studies to attain more knowledge concerning to fruits or rinds as a more sustainable material used for various reasons. Thus, this study was conducted.

Methods

This study was conducted at the Physical Sciences Laboratory in Don Pablo Lorenzo Memorial High School – Junior High School, Sta. Maria, Zamboanga City, Philippines. The experimental research design was used in this study is Complete Randomized Design (CRD). The researchers employed 3 CRDs for each of the experimental setups as explained further.

Table 1. shows the Complete Randomized Design (CRD) of the physically retted *M. domestica* peels for alternative multipurpose paper component. A total of 4 treatments were used, each with 4 replicates with 3 samples each replicate. For the physically retted *M. domestica* peels for alternative multipurpose paper component, the treatments were as follows: Treatment 1 – 25mL *M. domestica* Peels (AP), 35g Cornstarch (CS) & 60ml water; Treatment 2 – 30mL *M. domestica* Peels (AP), 40g Cornstarch (CS)& 55mL water; Treatment 3 – 40ml *M. domestica* Peels (AP), 55g Cornstarch (CS) & 50mL water; and Treatment 4 – commercial multipurpose paper (CMP). In preparing the treatments, the containers were placed on the desired place of the researchers. Secondly, the apple peels blended from earlier were placed in a bowl. Then, prepare 165mL of water, at least 60mL of apple peels from earlier and 120g of cornstarch. After, take one of the containers and begin the making of the first treatment, take 20 mL of AP, 35g CS and 60 mL of water and put them all in the first container then labelled it as treatment 1. Now, take another container and begin the making of the second treatment, take 30 mL AP, 40g CS and 55 mL of water and put them all in the second container then label it as treatment 2. Then, take the third container and begin the making of the third treatment, take 40mL AP, 55g CS and 50mL of water and put them all in the third container then label it as treatment 3. After, take a stirring rod and mixed all of them well. Mold and deckle and treatments were then prepared. Then, lay the fabric on a smooth surface and place the mould and deckle on it, slowly then pour the first mixture/first treatment on the mould and deckle to shape them like papers, do so for the other treatments. When all is done, take them out to sun dry for at least 2-3 days depending on the weather. Finally, after the papers have dried, cut them into pieces of $20cm^2$ for the durability testing.

Table 1. Experimental lay-out (CRD) the physically retted *M. domestica* peels for alternative multipurpose paper component.

$T_1R_3S_2$	$T_3R_2S_3$	$T_2R_3S_3$	$T_1R_1S_1$	$T_4R_2S_2$	$T_2R_1S_3$
$T_2R_2S_1$	$T_2R_2S_3$	$T_4R_2S_3$	$T_3R_3S_1$	$T_1R_3S_3$	$T_1R_3S_1$
$T_3R_1S_2$	$T_2R_1S_2$	$T_1R_2S_3$	$T_4R_3S_2$	$T_2R_3S_1$	$T_3R_3S_2$
$T_4R_3S_3$	$T_1R_4S_2$	$T_3R_2S_1$	$T_2R_3S_2$	$T_3R_2S_2$	$T_4R_1S_1$
$T_3R_4S_1$	$T_3R_1S_3$	$T_3R_4S_3$	$T_1R_2S_3$	$T_1R_4S_1$	$T_2R_4S_1$

$T_1R_1S_2$	$T_4R_2S_1$	$T_4R_1S_3$	$T_3R_3S_3$	$T_3R_2S_2$	$T_3R_1S_1$
$T_2R_4S_3$	$T_1R_2S_1$	$T_1R_1S_3$	$T_2R_4S_2$	$T_2R_1S_1$	$T_4R_4S_1$
$T_4R_1S_2$	$T_4R_4S_3$	$T_2R_2S_2$	$T_4R_3S_1$	$T_4R_4S_2$	$T_1R_4S_3$

Table 2. shows the Complete Randomized Design (CRD) of the physically retted dehydrated *A. heterophyllus* rind for alternative multipurpose paper component. A total of 4 treatments were used, each with 4 replicates with 3 samples each replicate. For the physically retted dehydrated *A. heterophyllus* rind for alternative multipurpose paper component, the treatments were as follows: Treatment 1 – 100g dehydrated *A. heterophyllus* rind (JFR) and 200g CS; Treatment 2 – 150g dehydrated *A. heterophyllus* rind (JFR) and 150g CS; Treatment 3 – 200g dehydrated *A. heterophyllus* rind (JFR) and 100g CS; and Treatment 4 – CMP. In preparing the treatments, the ripe *A. heterophyllus* were peeled and the fruit was put aside, the rinds were chopped into small pieces then placed onto a container for the drying process, the chopped rinds were sun-dried for three days. After sun-drying, the chopped rinds and CS were weighed according to its treatments and carefully them into the blender and pour 300mL of water for each treatment and blend until it became slurry. The researchers evenly poured the treatments to the deckle frame to mould the slurry. After moulding, the researchers placed the paper to a cloth for it to dry off. Finally, after the papers have dried, cut them into pieces of $20cm^2$ for the durability testing.

Table 2. Experimental lay-out (CRD) the physically retted dehydrated *A. heterophyllus* rind for alternative multipurpose paper component.

$T_3R_2S_3$	$T_4R_4S_2$	$T_2R_3S_2$	$T_1R_3S_3$	$T_1R_1S_3$	$T_4R_1S_3$
$T_1R_4S_3$	$T_3R_4S_2$	$T_3R_3S_3$	$T_3R_3S_2$	$T_2R_1S_2$	$T_1R_3S_1$
$T_3R_4S_3$	$T_4R_4S_1$	$T_2R_4S_3$	$T_2R_3S_1$	$T_4R_1S_1$	$T_2R_3S_3$
$T_1R_2S_2$	$T_1R_1S_1$	$T_3R_3S_1$	$T_4R_3S_1$	$T_1R_4S_1$	$T_3R_1S_1$
$T_2R_4S_1$	$T_1R_2S_3$	$T_1R_2S_1$	$T_3R_4S_1$	$T_4R_1S_2$	$T_4R_3S_3$
$T_1R_3S_2$	$T_4R_2S_3$	$T_3R_1S_2$	$T_4R_2S_2$	$T_2R_1S_3$	$T_1R_4S_2$
$T_2R_2S_1$	$T_2R_2S_2$	$T_2R_4S_2$	$T_2R_1S_1$	$T_3R_2S_2$	$T_2R_2S_3$
$T_4R_4S_3$	$T_4R_3S_2$	$T_3R_1S_3$	$T_4R_2S_1$	$T_3R_2S_1$	$T_1R_1S_2$

Table 3. shows the Complete Randomized Design (CRD) of the physically retted *M. indica* peels for alternative multipurpose paper component. A total of 4 treatments were used, each with 4 replicates with 3 samples each replicate. For the physically retted *M. indica* peels for alternative multipurpose paper component, the treatments were as follows: Treatment 1 – pure *M. indica* peels (MP); Treatment 2 – 200g *M. indica* peels (MP) and 100g CS; Treatment 3 – 200g *M. indica* peels (MP) and 150g Solvent Cement (SC); and Treatment 4 – CMP. In preparing the treatments, the researchers began by removing the peels from the *M. indica*. The peels were washed and cut into small pieces by the researchers. Third, the researcher placed them in a pot of boiling water. The peels were then dried before being placed in the blender. Once the *M. indica* peels are placed in the blender, the researchers first wait for them to become pulpy. After blending the *M. indica* peels, the researchers did the second treatment, which consisted of blending 200g of MP with 100g of CS. The third treatment was similar to the second since the researchers would simply blend 200g of MP and 150mL of SC in a blender. After preparing all of the treatments, the researchers placed them in each container and silkscreened them to make a paper shape. The researcher let each treatment dry after it had been silkscreened. After the papers have dried, the researcher finally cuts them into uniform $20cm^2$ squares to be able to distribute them to each container to test their durability.

Table 3. Experimental lay-out (CRD) the physically retted dehydrated *A. heterophyllus* rind for alternative multipurpose paper component.

$T_3R_1S_2$	$T_4R_2S_3$	$T_2R_4S_2$	$T_4R_3S_1$	$T_3R_1S_3$	$T_4R_1S_2$
$T_1R_1S_1$	$T_3R_4S_1$	$T_1R_4S_3$	$T_4R_4S_1$	$T_4R_1S_3$	$T_4R_2S_2$
$T_1R_1S_2$	$T_2R_3S_2$	$T_1R_2S_3$	$T_1R_2S_1$	$T_3R_3S_3$	$T_3R_3S_1$
$T_3R_4S_3$	$T_1R_4S_2$	$T_3R_2S_3$	$T_1R_3S_1$	$T_3R_2S_1$	$T_4R_1S_1$
$T_1R_3S_3$	$T_2R_3S_3$	$T_1R_3S_2$	$T_4R_3S_2$	$T_2R_4S_1$	$T_2R_4S_3$
$T_4R_3S_3$	$T_2R_1S_1$	$T_2R_1S_2$	$T_1R_1S_3$	$T_2R_2S_2$	$T_2R_3S_1$
$T_2R_2S_3$	$T_3R_1S_1$	$T_4R_4S_2$	$T_1R_2S_2$	$T_4R_2S_1$	$T_3R_4S_2$
$T_1R_4S_1$	$T_2R_1S_3$	$T_4R_4S_3$	$T_3R_2S_2$	$T_3R_3S_2$	$T_2R_2S_1$

The durability testing was done through immersing the 20cm^2 treatments into 1L of water. The treatments were laid flat, with 3cm deep into the water. The researchers then recorded the time in seconds for each of the treatments to break down into pieces and thus reflecting its durability. The data collected was subjected to data analysis. The researchers made use of the statistical analysis software – IBM Statistical Package for Social Sciences (SPSS) version 25. The following were the statistical tools used for analysis: Mean±SD, and One-way Analysis of Variance (ANOVA) at 0.05 level of significance and 95% confidence interval.

All the solid waste materials that were used in the experiment were gathered, separated, and disposed properly in the trash bin by the researchers. The liquid wastes were thrown at the sewages, following the Philippine Law on Ecological Solid Waste Management Act of 2000 (RA 9008).

Results and Discussion

Objective 1: Mean±SD durability in terms of time (seconds) it takes for the papers made from apple (*Malus domestica*) peels, dehydrated jackfruit (*Artocarpus heterophyllus*) rinds, and mango (*Mangifera indica*) peels to break down into pieces.

Table 4. Mean±SD durability in terms of time (seconds) it takes for the papers made from apple (*Malus domestica*) peels to break down into pieces.

TREATMENT	NO. OF SAMPLES	MEAN ± SD (seconds)
1 (25 mL AP, 35 g CS, 60 mL water)	12	46.83 ± 9.799
2 (35 mL AP, 40 g CS, 55 mL water)	12	60.67 ± 10.976
3 (40 mL AP, 55g CS, 50 mL water)	12	87.00 ± 5.585
4 CMP1	12	78.00 ± 0.000
	TOTAL: 48	

The table 4 shows the Mean±SD durability in terms of time (seconds) it takes for the papers made from apple (*Malus domestica*) peels to break down into pieces. Each treatment has 12 samples which is equal to 48 in total. For treatment 1, its Mean ± SD is 46.83 ± 9.799. For treatment 2, its Mean ± SD is 60.67 ± 10.976. For treatment 3, its Mean ± SD is 87.00 ± 5.585. And, for treatment 4, its Mean ± SD is 78.00 ± 0.000. Based on the results, it can clearly be seen that treatment 3 (87 ± 5.585) has the highest mean durability in terms of time (seconds) it take for the papers made from apple (*Malus domestica*) peels to break down into pieces produced among the 4 other treatments, while treatment 1 (46.83 ± 9.799) is the lowest durability in terms of time (seconds) it take for the papers made from apple (*Malus domestica*) peels to break down into pieces.

Table 5. Mean±SD durability in terms of time (seconds) it takes for the papers made from dehydrated jackfruit (*Artocarpus heterophyllus*) rinds to break down into pieces.

TREATMENT	NO. OF SAMPLES	MEAN ± SD (seconds)
1 (100g dehydrated *A. heterophyllus* rind (JFR) and 200g CS)	12	43.43 ± 7.381
2 (150g dehydrated *A. heterophyllus* rind (JFR) and 150g CS)	12	72.02 ± 10.402
3 (200g dehydrated *A. heterophyllus* rind (JFR) and 100g CS)	12	76.85 ± 21.551
4 CMP2	12	90.00 ± 0.000
	TOTAL: 48	

The table 5 shows the Mean±SD durability in terms of time (seconds) it takes for the papers made from dehydrated jackfruit (*Artocarpus heterophyllus*) rinds to break down into pieces. In treatment one 43.43 ± 7.381 is its Mean and Standard Deviation, 72.02 ± 10.402 in treatment 2, 76.85 ± 21.551 in treatment 3, and 90.00 ± 0.000 in treatment 4 which is the control variable. It is shown that treatment 3 is the most effective among the other two experimental setups, as for the reason that treatment 3 and 2 has a gap of 4.02 seconds and treatment 3 and 1 has a gap of 33.41 seconds. The first treatment has an average time of 43.43 seconds, the second treatment has an average of 72.02 seconds, the third treatment has an average time of 76.85 seconds, and lastly, the fourth treatment having the highest average time of 90 seconds.

Table 6. Mean±SD durability in terms of time (seconds) it takes for the papers made from mango (*Mangifera indica*) peels to break down into pieces.

TREATMENT	NO. OF SAMPLES	MEAN ± SD (seconds)
1 (pure *M. indica* peels (MP))	12	3230.25 ± 863.586
2 (200g *M. indica* peels (MP) and 100g CS)	12	233.67 ± 587.945
3 (200g *M. indica* peels (MP) and 150g Solvent Cement (SC))	12	82.92 ± 66.045
4 CMP3	12	3600.00 ± 0.000
	TOTAL: 48	

The table 6 shows the Mean±SD durability in terms of time (seconds) it takes for the papers made from mango (*Mangifera indica*) peels to break down into pieces. For treatment one, its Mean ± SD is 3230.25 ± 863.586 seconds, being the highest among the experimental setups. For treatment 2, 233.67 ± 587.945 seconds. For treatment 3, 82.92 ± 66.045 seconds, being the lowest among the experimental setups. And finally, for treatment 4, its Mean ± SD is 3600.00 ± 0.000 seconds, the control setup.

Objective 2: Significant difference of the durability in terms of time (seconds) it takes for the papers made from apple (*Malus domestica*) peels, dehydrated jackfruit (*Artocarpus heterophyllus*) rinds, and mango (*Mangifera indica*) peels to break down into pieces when compared to a commercial multipurpose paper.

Table 7. Analysis of Variance (ANOVA) of the durability in terms of time (seconds) it takes for the papers made from apple (*Malus domestica*) peels to break down into pieces when compared to CMP1.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	11557.630	3	3852.543	57.023	**.000***
Within Groups	2972.708	44	67.562		
Total	14530.338	47			

**highly significant (P-value=0.000<α=0.05)*

Table 7 shows the Analysis of Variance (ANOVA) of the durability in terms of time (seconds) it takes for the papers made from apple (*Malus domestica*) peels to break down into pieces when compared to CMP1. It shows a significant difference on the durability in terms of time (seconds) it takes for the papers made from apple (*Malus domestica*) peels to break down into pieces when compared to CMP1 with the *P*-value is 0.000, which is less than the alpha level of 0.05, in that case the researchers will thus now reject the null hypothesis and consider that there is a significant difference on the durability in terms of time (seconds) it takes for the papers made from apple (*Malus domestica*) peels to break down into pieces when compared to CMP1.

Table 8. Tukey HSD Post-Hoc Analysis of the durability in terms of time (seconds) it takes for the papers made from apple (*Malus domestica*) peels to break down into pieces when compared to CMP1.

	(I) TREATMENTS	(J) TREATMENTS	Mean Difference (I-J)	Std. Error	Sig.
Tukey HSD	T4 CMP1	T1 (25 mL AP, 35 g CS, 60 mL water)	40.18167**	3.35563	**0.000****
		T2 (35 mL AP, 40 g CS, 55 mL water)	26.34000**	3.35563	**0.000****
		T3 (40 mL AP, 55g CS, 50 mL water)	9.01750*	3.35563	**0.048***

***highly significant (P-value=0.000<α=0.05)*

**significant (P-value=0.048<α=0.05)*

Furthermore, as shown in Table 8, there is a significant difference between the durability in terms of time (seconds) it takes for the papers to break down into pieces made from Treatment 1 (25 mL AP, 35 g CS, 60 mL water) and Treatment 2 (35 mL AP, 40 g CS, 55 mL water) apple (*Malus domestica*) peels when compared to CMP1. Given with the Mean ± SD is 46.83 ± 9.799 seconds of Treatment 1 (25 mL AP, 35 g CS, 60 mL water) and Mean ± SD is 60.67 ± 10.976 seconds of Treatment 2 (35 mL AP, 40 g CS, 55 mL water), when compared to CMP1 of 78.00 ± 0.000 seconds, it shows that the CMP1 performs better significantly higher compared to Treatment 1 (25 mL AP, 35 g CS, 60 mL water) and Treatment 2 (35 mL AP, 40 g CS, 55 mL water) of papers made from *M. domestica* peels. Thus, in the premise of this research, it was shown that papers made from *M. domestica* in terms of its durability are poorer compared to the CMP1. It was also found out that the CMP1 is significantly better in terms of durability when compared to Treatment 3 (40 mL AP, 55g CS, 50 mL water), with Mean ± SD 76.85 ± 21.551 seconds. *M. domestica* peels contain cellulose, by further examining the cellulosic lamellar structure located on the surface of apple fruit skin revealed that it is composed of dense cellulose networks (Wang, et al., 2022). However, it has been reported that when 0.039% w/v of glycerol, and 15.7% of w/w chitosan in the 3% solid pulp were used, together with 26.9% w/w of rhubarb pomace, it shall yield an optimum pulp formulation with the superhydrophobic coating further enhanced the water resistance of the board and the developed boards were compostable in soil (Lang, Jung, Wang, & Zhao, 2022). Thus, studies with the use of *M. domestica* peels and its fibers could potentially bring new insights into water resistant and compostable packaging for multiple purposes.

Table 9. Analysis of Variance (ANOVA) of the durability in terms of time (seconds) it takes for the papers made from dehydrated jackfruit (*Artocarpus heterophyllus*) rinds to break down into pieces when compared to CMP2.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	13866.590	3	4622.197	29.481	**.000***
Within Groups	6898.459	44	156.783		
Total	20765.049	47			

**highly significant (P-value=0.000<α=0.05)*

Table 9 shows the Analysis of Variance (ANOVA) of the durability in terms of time (seconds) it takes for the papers made from dehydrated jackfruit (*Artocarpus heterophyllus*) rinds to break down into pieces when compared to CMP2. It shows a significant difference on the durability in terms of time (seconds) it takes for the papers made from dehydrated jackfruit (*Artocarpus heterophyllus*) rinds to break down into pieces when compared to CMP2 with the *P*-value is 0.000, which is less than the alpha level of 0.05, in that case the researchers will thus now reject the null hypothesis and consider that there is a significant difference on the durability in terms of time (seconds) it takes for the papers made from dehydrated jackfruit (*Artocarpus heterophyllus*) rinds to break down into pieces when compared to CMP2.

Table 10. Tukey HSD Post-Hoc Analysis of the durability in terms of time (seconds) it takes for the papers made from dehydrated jackfruit (*Artocarpus heterophyllus*) rinds to break down into pieces when compared to CMP2.

	(I) TREATMENTS	(J) TREATMENTS	Mean Difference (I-J)	Std. Error	Sig.
Tukey HSD	T4 CMP2	T1 (100g dehydrated *A. heterophyllus* rind (JFR) and 200g CS)	46.56833*	5.11180	**.000****
		T2 (150g dehydrated *A. heterophyllus* rind (JFR) and 150g CS)	17.97833*	5.11180	**.005***
		T3 (200g dehydrated *A. heterophyllus* rind (JFR) and 100g CS)	13.15083	5.11180	.063

***highly significant (P-value=0.000<α=0.05)*

**significant (P-value=0.005<α=0.05)*

Furthermore, as shown in Table 10, there is a significant difference between the durability in terms of time (seconds) it takes for the papers to break down into pieces made from Treatment 1 (100g dehydrated *A. heterophyllus* rind (JFR) and 200g CS) and Treatment 2 dehydrated jackfruit (*Artocarpus heterophyllus*) rinds when compared to CMP2. Given with the Mean ± SD is 43.43 ± 7.381 seconds of Treatment 1 (100g dehydrated *A. heterophyllus* rind (JFR) and 200g CS) and Mean ± SD is 72.02 ± 10.402 seconds of Treatment 2 (150g dehydrated *A. heterophyllus* rind (JFR) and 150g CS), when compared to CMP2 of 90.00 ± 0.000 seconds, it shows that the CMP2 performs better significantly higher compared to Treatment 1 (100g dehydrated *A. heterophyllus* rind (JFR) and 200g CS) and Treatment 2 (150g dehydrated *A. heterophyllus* rind (JFR) and 150g CS) of papers made from dehydrated jackfruit (*Artocarpus heterophyllus*) rinds. Thus, in the premise of this research, it was shown that papers made from dehydrated jackfruit (*Artocarpus heterophyllus*) rinds in terms of its durability are poorer compared to the CMP. However, it was also found that Treatment 3, which is composed of 200g dehydrated *A. heterophyllus* rind (JFR) and 100g CS with Mean ± SD of 76.85 ± 21.551 seconds has no significant difference when compared to CMP2. This implies that, in the premise of this research, the Treatment 3 (200g dehydrated *A. heterophyllus* rind (JFR) and 100g CS) is statistically similar with CMP2 in terms of durability, providing its potential for alternative CMP2 component. It has been observed that the Treatment with the highest amount of dehydrated *A. heterophyllus* rind (JFR) yielded statistically similar with CMP2, which implies that physically retted dehydrated *A. heterophyllus* rind (JFR) can be used as an alternative component to CMP as a ripe *A. heterophyllus* has high cellulose fibers, it has 59% peel, which is a rich source of pectin in the form of calcium pectate, that is made up of 27.75% cellulose, 7.52% pectin, 6.27% protein, and 4% starch (Begum, Aziz, Uddin, & Yusof, 2014). Also, contributing to the compostable nature of dehydrated *A. heterophyllus* rind (JFR) is that it can be possibly used to improve crop productivity as it can decompose anaerobically and can also be used as a briquette (Nsubuga, Banadda, Kabenge, & Wydra, 2020), providing various alternatives for CMP with physically retted dehydrated *A. heterophyllus* rind (JFR) component after usage.

Table 11. Analysis of Variance (ANOVA) of the durability in terms of time (seconds) it takes for the papers made from mango (*Mangifera indica*) peels to break down into pieces when compared to CMP3.

	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	128240204.083	3	42746734.694	156.035	**.000***
Within Groups	12054037.833	44	273955.405		
Total	140294241.917	47			

**highly significant (P-value=0.000<α=0.05)*

Table 11 shows the Analysis of Variance (ANOVA) of the durability in terms of time (seconds) it takes for the papers made from mango (*Mangifera indica*) peels to break down into pieces when compared to CMP3. It shows a significant difference on the durability in terms of time (seconds) it takes for the papers made from mango (*Mangifera indica*) peels to break down into pieces when compared to CMP3 with the *P*-value is 0.000, which is less than the alpha level of 0.05, in that case the researchers will thus now reject the null hypothesis and consider that there is a significant difference on the durability in terms of time (seconds) it takes for the papers made from mango (*Mangifera indica*) peels to break down into pieces when compared to CMP3.

Table 12. Tukey HSD Post-Hoc Analysis of the durability in terms of time (seconds) it takes for the papers made from mango (*Mangifera indica*) peels to break down into pieces when compared to CMP3.

	(I) TREATMENTS	**(J) TREATMENTS**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**
Tukey HSD	T4 CMP3	T1 (pure *M. indica* peels (MP))	369.75000	213.68021	0.321
		T2 (200g *M. indica* peels (MP) and 100g CS)	3366.33333*	213.68021	**0.000****
		T3 (200g *M. indica* peels (MP) and 150g Solvent Cement (SC))	3517.08333*	213.68021	**0.000****

***highly significant (P-value=0.000<α=0.05)*

Furthermore, as shown in Table 12, there is a significant difference between the durability in terms of time (seconds) it takes for the papers to break down into pieces made from Treatment 2 (200g *M. indica* peels (MP) and 100g CS) and Treatment 3 (200g *M. indica* peels (MP) and 150g Solvent Cement (SC)) mango (*Mangifera indica*) peels when compared to CMP3. Given with the Mean ± SD is 233.67 ± 587.945 seconds of Treatment 2 (200g *M. indica* peels (MP) and 100g CS) and Mean ± SD is 82.92 ± 66.045 seconds of Treatment 3 (200g *M. indica* peels (MP) and 150g Solvent Cement (SC)), when compared to CMP3 of 3600.00 ± 0.000 seconds, it shows that the CMP3 performs better significantly higher compared to Treatment 2 (200g *M. indica* peels (MP) and 100g CS) and Treatment 3 of papers made from mango (*Mangifera indica*) peels. Thus, in the premise of this research, it was shown that papers made from mango (*Mangifera indica*) peels in terms of its durability are poorer compared to the CMP3. However, it was also found that Treatment 1, which is composed of pure *M. indica* peels (MP) with Mean ± SD of 3230.25 ± 863.586 seconds has no significant difference when compared to CMP3. This implies that, in the premise of this research, the Treatment 1 (pure *M. indica* peels (MP)) is statistically similar with CMP3 in terms of durability, providing its potential for alternative CMP3 component. It supports the study that since cellulose is the primary component of the chemical composition of *M. indica* peels (Yingkamhaeng & Sukyai, 2014), in which fibers made of cellulose are extremely strong and long-lasting. They are hygroscopic, or readily absorb significant amounts of water when exposed to the atmosphere. They are easily wetted by water, exhibiting significant swelling when saturated. Natural cellulose fibers exhibit no strength loss, even when wet (Britt, 2020). In summary, it was found that the durability in terms of time (seconds) it takes for the papers made from dehydrated *A. heterophyllus* rind T3 (200g dehydrated *A. heterophyllus* rind (JFR) and 100g CS) and *M. indica* peels T1 (pure *M. indica* peels (MP)) to break down into pieces is comparably similar with commercial multipurpose paper.

4. Conclusions and Recommendations

Based on the gathered data and upon its analysis, papers from dehydrated *A. heterophyllus* rind Treatment 3 (200g dehydrated *A. heterophyllus* rind (JFR) and 100g CS) with Mean ± SD of 76.85 ± 21.551 seconds took for it to break down into pieces and *M. indica* peels Treatment 1 (pure *M. indica* peels (MP)) with Mean ± SD of 3230.25 ± 863.586 seconds took for it to break down into pieces yielded statistically similar results to commercial multipurpose paper. Therefore, based on comparative durability to commercial multipurpose paper, dehydrated *A. heterophyllus* rind and pure *M. indica* peels can potentially be used as a component in making multipurpose paper. Furthermore, it can be recommended to: 1. Determine the quality of the papers produced using standardized paper quality testing; 2. Use standardized paper quality components in synergy with fibers from dehydrated *A. heterophyllus* rind and pure *M. indica* peels; and 3. Study the effects of the fibers physically retted from dehydrated *A. heterophyllus* rind and pure *M. indica* peels on the quality of the multipurpose papers produced.

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