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CHARACTERIZATION OF CALAMONDIN *(Citrofortunella microcarpa)* IN PAPER MAKING USING GREEN BINDERS

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Abstract: This study aimed to characterize Calamondin (*Citrofortunella microcarpa*) in paper making using green binders. This also aimed to produce sustainable and eco-friendly products utilizing agro-waste materials. It also specifically sought to evaluate the physical characteristics, acceptability and significant difference in terms of appearance, texture, foldability, fiber dispersion, and opacity of paper from Calamansi pulp using green binders. Developmental research design was used, formulating three treatments.

The participants of the study were composed 25 professionals (handmade paper maker, interior designer, architectural and drafting instructors, and local artists) and 25 students (BIndTech drafting students). Score cards with Five-point Likert Scale was used to obtain the data. The mean and Analysis of Variance (ANOVA) were used to analyze the data into alpha level set at 0.05.

Results of the data collected revealed that the physical characteristics of the calamondin *(Citrofortunella microcarpa)* in paper making using green binders, in terms of appearance, Treatment B (500g calamondin fruit pulp with 500g taro runner pulp) is the best. In terms of texture, foldability, fiber dispersion, and opacity, Treatment A (500g calamondin fruit pulp with 387g malabar spinach stem pulp) got the highest mean scores. The product also revealed that there is no significant difference in terms of appearance and fiber dispersion, however, in terms of texture, foldability and opacity has significant difference. Treatment A (500g calamondin fruit pulp with 387g malabar spinach stem pulp) turned out to be "Very Acceptable" in terms of appearance, texture, foldability, fiber dispersion, and opacity.

Better heavy pressing equipment and more other product conversions and developments were suggested and recommended by the experts to further enhance the quality and to maximize the functionality of the calamondin handmade paper with green binders.

Keywords: Handmade paper, Green Binders, Eco-friendly, Sustainable, Agro-waste, Product Conversion.

I. INTRODUCTION

Industrialization was designed to promote livelihood programs to elevate the economic status of the community, yet, it resulted to different agricultural-waste products that leads to environmental pollution, illnesses and has a great impact to global warming. Factories may have their landfill or compost pits, yet, calamondin fruit residues cannot be considered as a source of fertilizers due to its very high acidity level. With this, an addition and an alternative to the compost pit must be initiated to control such concern.

During the first three months of the Enhanced Community Quarantine due to Covid-19, the calamondin juice production decreased, and harvesting or bulk buying of the fresh calamondin fruits to supply markets and other provinces were discontinued for a while. Because of this, all calamondin fruits became overripe and fell off their trees. Such wastage and the decline of the economy due to the pandemic saddened the whole community.

During the 18th century in Europe, handmade paper making technology was widely accepted and considered as one of the very important discoveries before the development of industrialized wood pulp-based paper industry. This contemporary method fucoses on the development of vast types of paper to cover the needs of the masses and to earn profits at any cost. Industrialized production of paper wrecked handmade paper production. Modern practices in papermaking threatens the environment.

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The extensive use of wood pulp and harmful chemicals could lead to deforestation that causes environmental concerns such as pollution, illnesses, floods and landslides. This insensible use of natural resources has become hazards to us.

To lessen agro-waste and to develop an eco-friendly and can be a new income-generating and product for the community, the researcher came up with a handmade paper from raw materials collected from the wastes/residues from the running factories around. The researcher studied and developed handmade paper using the citrus fruit, calamondin, which was discarded from a calamondin juice manufacturing establishment as its raw material. The idea of using plant-based or green binders to enhance and strengthen the paper was also incorporated in the study.

The study aimed to characterize calamondin *(Citrofortunella microcarpa)* in paper making using green binders such Treatment A (calamondin fruit pulp with malabar spinach stems pulp), Treatment B (calamondin fruit pulp with taro runners pulp, and Treatment C (calamondin fruit pulp with okra fruit pulp). Specifically, it sought to: (1) describe the physical characteristics of paper from calamondin fruit pulp in terms of appearance, texture, foldability, fiber dispersion, and opacity; (2) find out if there is a significant difference in the physical characteristics of the paper in terms of appearance, texture, foldability, fiber dispersion, and opacity of paper from calamondin pulp using green binders and; (3) determine the acceptability of paper from calamondin fruit pulp in terms of appearance, texture, foldability, fiber dispersion, and opacity when utilized as novelty paper, picture frame and lamp shade.

II. METHODOLOGY

Phases	Description
Phase I	**Developmental Design**
Phase II	**Experimental Treatment**
Phase III	**Collection of Data**
Phase IV	**Instrumentation**
Phase V	**Statistical Tools and Analysis**

Methodology: Phase I Developmental Design

- Completely Randomized Design (CRD) will be employed to generate data. Samples for evaluation were coded and score cards were utilized for randomization.
- Developmental Research Design was employed in this study to determine the result of the different treatments in the characterization of the handmade novelty paper from calamondin with different green binders in terms of physical characteristics. This study was conducted using a questionnaire and validated through the mean of the results with the factors considered.

Methodology: Phase II Experimental Treatment

In this study, the pulping process requires same ratio and proportions of caustic soda or sodium hydroxide (NaOH) of 1% across the four raw materials such as the calamondin fruit pulp (8 kg raw calamansi fruit pulp, 80 g NaOH) and the three different green binders: Treatment A (2.5 kg malabar spinach stems, 25 g NaOH), Treatment B (2 kg taro runners, 20 g NaOH), and Treatment C (2 kg okra fruit, 20 g NaOH)

Table 1. Ratio and proportions of the raw materials and the three (3) treatments during the pulping process

Ingredients and Process	Calamondin Fruit Pulp	**Treatment A** Malabar Spinach Stem Pulp	**Treatment B** Taro Runner Pulp	**Treatment C** Okra Fruit Pulp
Raw Material Prior to Pulping	8 kg	2.5 kg	2 kg	2 kg
Caustic Soda (1%)	80 g	25 g	20 g	20 g
Boiling Time	30 min	15 min	8 min	1 hour
Extracted fiber	2.622 kg	387 g	1.388 kg	1.043 g

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The workspace, tools, materials, and materials were gathered and prepared. The raw materials were sliced into 1 ½ in – 2 in in length and washed if necessary. The whole production of the calamondin handmade paper had undergone into stages of processing starting with the pulping stage. The calamondin fruit residue, malabar spinach stem, taro runners, and okra fruit were treated in 1% caustic soda or sodium hydroxide (NaOH) in a simmering water. The doneness of each raw material was checked every 5 mins or until they soft enough to separate fibers easily when pinched.

After boiling, the pulps were rinsed thoroughly in running water. The moisture from the pulp was then squeezed out using an organza cloth until the pulp can hold a shape or can be formed into a ball. For the refining stage, the pulps from the four raw materials were beaten using a food processor with water for 30 seconds or until fibers became finer and separated. The pulps were again squeezed using an organza cloth ensuring most water was removed.

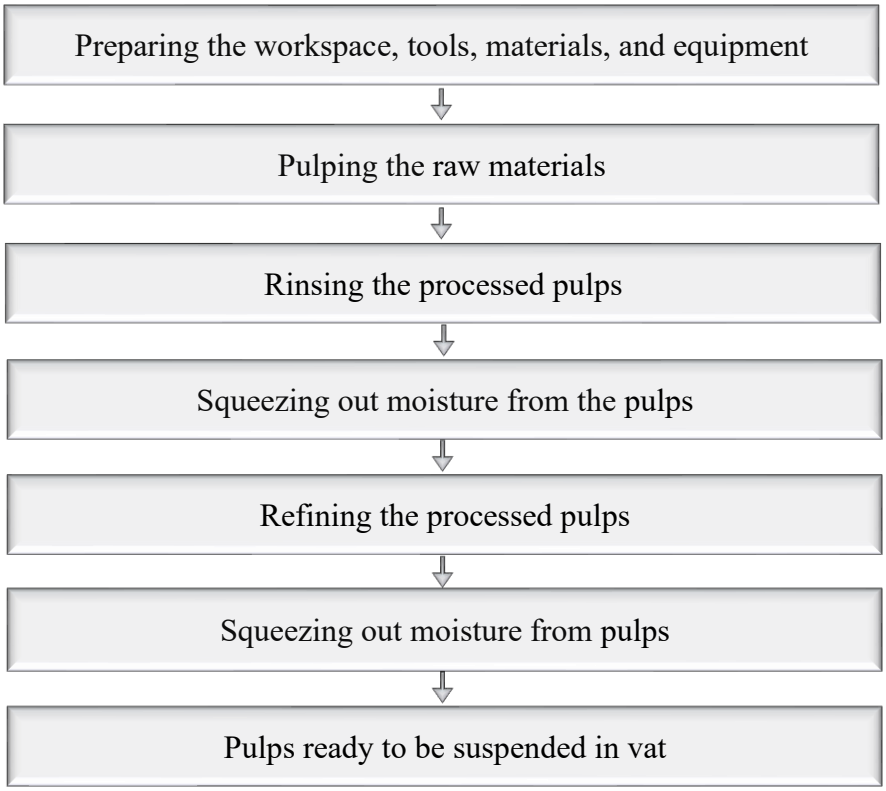

Fig 1. Flowchart of the pulping process of the calamondin fruit pulp.

For the sheet forming, three different vats carried out calamondin fruit pulp with different green binder treatments suspended in water with the following ratio and proportions: **Treatment A** (500 g calamondin pulp, 387 g malabar spinach stems pulp, 10 L water), **Treatment B** (500 g calamondin, 500 g taro runners pulp, 10 L water), and **Treatment C** (500 g calamondin, 500 g okra fruit pulp, 10 L water).

Table 2. Ratio and proportions of the calamansi fruit pulp in three (3) treatments suspended in vat.

Ingredients and Process	**Treatment A** Calamondin Fruit Pulp with Malabar Spinach Stem Pulp	**Treatment B** Calamondin Fruit Pulp with Taro Runner Pulp	**Treatment C** Calamondin Fruit Pulp with Okra Fruit Pulp
Calamondin Fruit Pulp	500 g	500 g	500 g
Malabar Spinach Stem Pulp	387 g		
Taro Runner Pulp		500 g	
Okra Fruit Pulp			500 g
Water	10 L	10 L	10 L

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Ten liters (10 L) of clean water was poured in a 20 L-capacity storage box. One (1) vat for each treatment is used in this process. The processed pulps were suspended into the water-filled vats. The first vat consisted of a 500 grams ball of calamondin fruit pulp and a 387 grams ball of Treatment A (malabar spinach stem pulp). The second vat consisted of a 500 grams ball of calamondin fruit pulp and a 500 grams ball of Treatment B (taro runners pulp). And the third vat consisted of a 500 grams ball of calamondin fruit pulp and a 500 grams ball of Treatment C (okra fruit pulp). The suspended pulps were stirred with a hand for even fiber dispersion and were left soaked in vats for five (5) hours to overnight for a nicer and smoother pulp.

To form a sheet, the pulp mixture in vat was stirred first by hand protected with gloves. The deckle was placed over the mold. The mold and deckle were held together firmly and immersed vertically into the far side of the vat. The movements were kept as smooth as possible until the mold and deckle were in the horizontal position. The frame was pulled in front of the vat until totally immersed upward out of the pulp mixture. The mold and deckle were held over the vat, were slightly tilted to allow excess water to drain away from the formed sheet. The deckle was carefully removed from the mold, making sure that no drips fell into the formed sheet. Excess water was removed from the mold by running a sponge underneath the mold until it felt light. A non-woven interfacing was laid on top of the mold with the formed sheet and was flipped over quickly. The formed sheets were transferred by again, running a sponge at the back of the mold to absorb more water while pressing the sheets to the non-woven interfacing. This process was done carefully to avoid bubbles and breakage during the transfer. Approximately 50% to 60% water has been removed from the sheets.

Two (2) to four (4) more non-woven interfacings were piled in between the formed sheets and was put under a heavy press for 12 to 24 hours. This process was done to further absorb excess water from the formed sheets up to 90%. Good pressing techniques and the absence of moisture resulted to very high-quality handmade paper. Remove C-clamps after 12 to 24 hours of heavy pressing.

The sheets were carefully removed from being piled up. The pressed damped calamondin paper sheets were transferred to plywood boards for the final drying process. Plywood boards (scraps), approximately 13 inches by 28 inches (or any size enough to hold the formed sheets) were laid on top of the non-woven interfacing where the damped calamondin paper sheet is attached. The edges of the non-woven interfacing and the plywood were held together making sure that the calamondin sheet was secured and they were flipped over on the other side as quickly as possible to prevent the calamondin paper sheet from deforming and falling. With the non-woven interfacing on top of the plywood, a sponge was run through the interfacing to further remove excess water. The non-woven interfacing was gently removed from the calamondin paper sheet by supporting with a sponge. This process was done to avoid breakage and deformities on the calamondin paper sheet while it was being transferred on a plywood board.

Gluing technique was necessary to prevent shrinkage during the drying process considering calamondin fruit and the green binders have very weak and delicate fibers. In this stage, cassava starch was used as a green glue. An ample amount of green glue was brushed in all the sides of the calamondin paper sheet. The paper sheets were air dried for at least one (1) hour before the same cassava starch glue was applied as a top coat for the entire sheet with a brush. This enhanced the appearance of the calamondin paper sheet as well as strengthens the holding ability of the fibers to avoid breakage in the middle section of the sheet. Place the plywood boards with the calamondin paper sheets in an area or room with good source of airflow.

The sheets were air dried for 12 to 48 hours. Drying time depended on the thickness of each sheet of paper. Weather and temperature were also great factors to the length of drying. The calamondin paper sheets were removed when fully dried. With a cutter, the calamondin paper sheets were carefully removed. The process started at the corner to avoid damage of the paper. The dried calamondin decorative handmade paper sheets were then converted into lampshades and picture frame side moldings as its end product.

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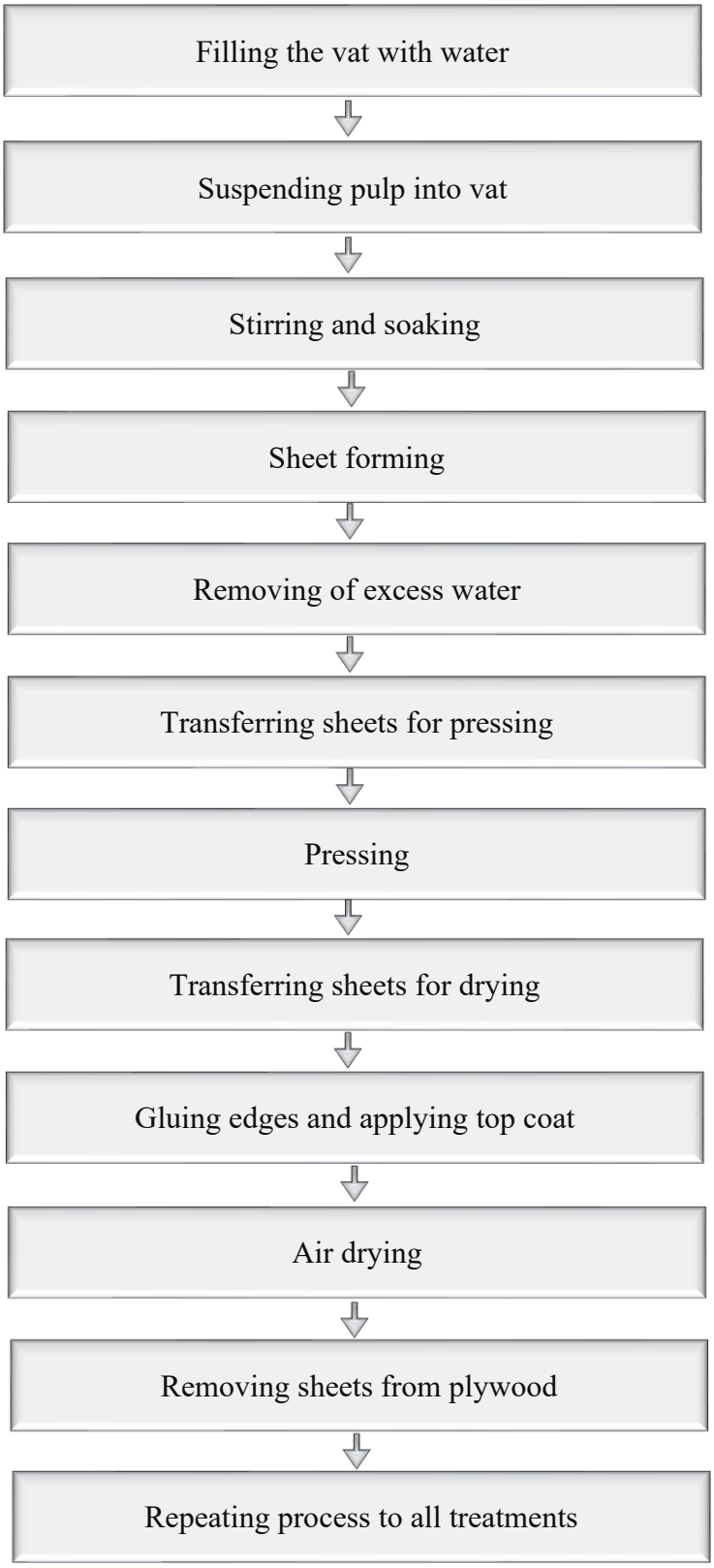

Fig 2. Flowchart of the sheet forming, pressing and drying process.

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For the preparation of the green glue, three (3) tablespoons of cassava starch were diluted with approximately one-eighth (1/8) cup of water in a small mixing bowl. Two (2) cups of water were boiled in a small casserole. The diluted cassava starch was gradually poured while stirring over a low heat. The mixture was cooked until it was translucent and thick in consistency as commercial glue.

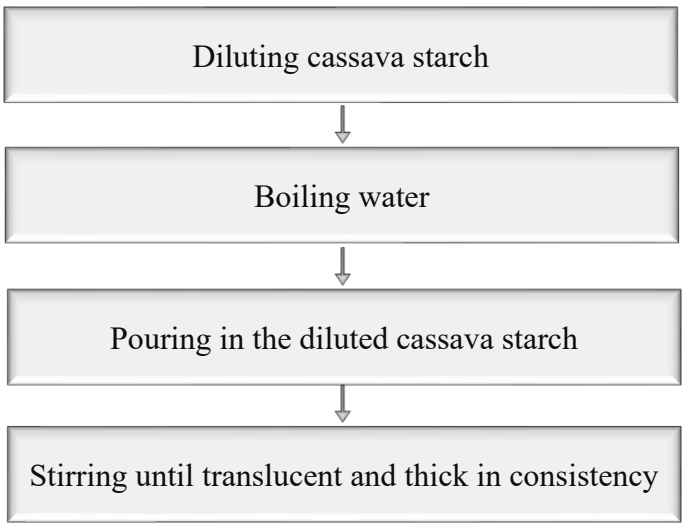

Fig 3. Flowchart of green glue processing.

Methodology: Phase III Collection of Data

To gather data for the characterization of calamondin in paper making using green binders, a systematic data gathering procedure was essential. The researcher utilized the calamondin paper sheets into a frame decorative moldings and light cover for lampshades. The decorative calamondin handmade paper with green binders was evaluated by a panel of 25 experts as to sensory evaluation in three treatments. The panel of experts were composed of: 17 drafting professors/instructors from Capiz State University, Main Campus; 8 were handmade paper maker/entrepreneur, interior design graduate, visual artists, printing and souvenir shop owner, draftsman; and teachers from Capiz National High School, under the Technology and Livelihood Education Department handling drafting and handicraft subjects. They were selected due to their educational preparation and profession, and were requested personally by the researcher to be among the panelists for the sensory evaluation of the products. 25 college students taking drafting/visual arts subjects from Capiz State University, Main Campus were also requested to evaluate the product.
The ratings were expressed in terms of the degree of conformity to the given sensory qualities of the product indicated in the verbal description of the scale. Samples for evaluation were coded and score cards were utilized for the evaluation. It investigated the sensory characteristics in terms of appearance, texture, foldability, fiber dispersion, and opacity. These five characteristics were included in determining the general acceptability of calamondin handmade novelty/decorative paper with green binders.

Methodology: Phase IV Instrumentation

The instrument used in gathering of the data is the sensory evaluation sheet. The items presented in the evaluation sheet were the basis for determining the level of acceptability of calamondin paper with green binders. It deals with the variables used to evaluate the products in terms of appearance, texture, foldability, fiber dispersion and opacity. There are five (5) response categories for each variable and each category is given appropriate or corresponding weight or rank value based on the five-point likert scale. The criteria (Score Sheets) was presented to a jury of five and the result of the evaluation. The responses of the fifty (50) evaluators in each three treatments averaged.

Methodology: Phase V Statistical Tools and Analysis

After the evaluation of the product, the score sheets were gathered, tallied, and summarized for computation.
The following statistical tools were used in this study are Frequency Count and Mean, Standard Deviation, One-Way Analysis of Variance (ANOVA), Tukey HSD Post Hoc Test, and the level of significance is set at 0.05.

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III. RESULTS AND DISCUSSION

Physical Characteristics of Paper from Calamondin Fruit Pulp

Table 3 has covered the physical characteristics of paper from calamondin fruit pulp in terms of appearance, texture, foldability, fiber dispersion, and opacity. The data showed that in terms of appearance, Treatment B (calamondin fruit pulp with taro runners pulp) verbally interpreted "Very Appealing" with the highest mean score of 4.40 mean. Followed by Treatment A (calamondin fruit pulp with malabar spinach stems pulp), was interpreted as "Very Appealing" with the mean score of 4.38. And lastly, Treatment C (calamondin fruit pulp with okra fruit pulp), still interpreted as "Very Appealing" with the mean score of 4.32.

This result supported the earlier findings that handmade paper does not only served functional purposes but also add an aesthetic charm to various projects (Saini, 2023). In terms of texture, Treatment A (calamondin fruit pulp with malabar spinach stems pulp) was the highest rated as "Very Fine" with mean score of 4.32. Followed by Treatment B (calamondin fruit pulp with taro runners pulp) with the interpretation as "Fine" with mean score of 3.96. And Treatment C (calamondin fruit pulp with okra fruit pulp) with the interpretation as "Fine" with mean score of 3.70. This finding supports the article of Saini (2023) that defines a type of handmade paper with a variety of textures ranging from subtle to pronounced, the handmade texture paper adds depth and dimension to artistic endeavors. It serves as a versatile backdrop for a wide range of projects, from mixed media art to scrapbooking.

Treatment A (calamondin fruit pulp with malabar spinach stems pulp) shows the highest mean score in terms of Foldability and verbally interpreted as "Very Foldable" as supported by the 4.32 mean. Followed by Treatment B (calamondin fruit pulp with taro runners pulp) verbally interpreted as "Foldable" as supported by the 3.94 mean. And Treatment C (calamondin fruit pulp with okra fruit) has the lowest score of 3.56 mean, still verbally interpretated as "Foldable". The results can be associated with the work of Sannapapamma et al. (2020), wherein it was expressed there that due to fiber inherent microstructure and effective fiber bonding during pulping leads to even soft and pliable structure contributed better folding endurance property of a handmade paper.

In terms of Fiber Dispersion, Treatment A (calamondin fruit pulp with malabar spinach stems pulp) shows the highest score of 4.26 mean and was verbally interpreted as "Highly Attractively Dispersed Evenly". Treatment B (calamondin fruit pulp with taro runners pulp) falls on the second place with a 4.16 mean score and verbally interpreted as "Attractively Dispersed Evenly". And Treatment C (calamondin fruit pulp with okra fruit pulp) shows the lowest score of 4.04 and was verbally interpreted as "Attractively Dispersed Evenly". This result aligns with how Bendinsken defines fiber dispersion, to even out the fibrous material (Bendiksen, 2023). The result means that treatment A (calamondin fruit pulp with malabar spinach stems pulp) has the most carefully dispersed fibers during the sheet forming process.

Treatment A (calamondin fruit pulp with malabar spinach stems pulp) also shows the highest score in terms of Opacity with 3.70 mean and was verbally interpreted as "Translucent". Followed by Treatment B (calamondin fruit pulp with taro runners pulp) with 3.66 mean and was interpreted as "Moderately Translucent". Lastly, Treatment C (calamondin fruit pulp with okra fruit pulp) got the lowest with a score of 3.50 mean and was interpreted as "Moderately Translucent". This finding indicated that Treatment A (calamondin fruit pulp with malabar spinach stems pulp) was the most "Translucent" among the treatments. This means that Treatment A (calamondin fruit pulp with malabar spinach stems pulp) was not opaque. Opacity or being opaque refers to the degree that a substrate was able to block the transmission of visible light (Hilldale, 2025). The paper's translucence depends on how the fibers absorb or reflect the light (Bachmann, ©2025).

Overall, Treatment B (calamondin fruit pulp with taro runners pulp) is the best in terms of appearance and Treatment A (calamondin fruit pulp with malabar spinach stems pulp) outperforms Treatments B (calamondin fruit pulp with taro runners pulp) and C (calamondin fruit pulp with okra fruit pulp) in terms of texture, foldability, fiber dispersion, and opacity indicating its superior quality. These findings provide valuable insights for artists, researchers, and manufacturers seeking to optimize the use of agro-waste and perennial plants around. This was also aligned in the work of Favini cited by Dylan (2025) stating that the plant residues and agro-wastes that was salvaged from the dumping grounds to be utilized in producing papers have an unusual aesthetic and tactile appearance. It was also emphasized that these papers from wastes manifests good quality and tensile strength.

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Table 3. Physical characteristics of paper from calamondin pulp in terms of appearance, texture, foldability, fiber dispersion, and opacity.

Treatments	Appearance		Texture		Foldability		Fiber Dispersion		Opacity	
	Mean	VI	**Mean**	VI	**Mean**	VI	**Mean**	VI	**Mean**	VI
Treatment A (Calamondin fruit pulp 500g, malabar spinach stems pulp 387g, water 10 L)	4.38	**VA**	4.32	**VF**	4.32	**VF**	4.26	**HADE**	3.70	**VT**
Treatment B (Calamondin fruit pulp 500g, taro runners pulp 500g, water 10 L)	4.40	**VA**	3.96	**F**	3.94	**F**	4.16	**ADE**	3.66	**T**
Treatment C (Calamondin fruit pulp 500g, okra fruit pulp 500g, water 10 L)	4.32	**VA**	3.70	**F**	3.56	**F**	4.04	**ADE**	3.50	**T**

Legend: *Adjectival Description (AD)*

Scale	*Verbal Interpretation (VI) in Appearance*	*Scale*	*Verbal Interpretation (VI) in Texture*
4.21 – 5.00	*Very Appealing (VA)*	*4.21 – 5.00*	*Very Fine (VF)*
3.41 – 4.20	*Appealing (A)*	*3.41 – 4.20*	*Fine (F)*
2.61 – 3.40	*Moderately Appealing (MA)*	*2.61 – 3.40*	*Moderately Fine (MF)*
1.81 – 2.60	*Less Appealing (LA)*	*1.81 – 2.60*	*Rough (R)*
1.0 – 1.80	*Not Appealing (NA)*	*1.0 – 1.80*	*Very Rough (VR)*

Scale	*Verbal Interpretation (VI) in Foldability*	*Scale*	*Verbal Interpretation (VI) in Fiber Dispersion*
4.21 – 5.00	*Very Foldable (VF)*	*4.21 – 5.00*	*Highly Attractively Dispersed Evenly (HADE)*
3.41 – 4.20	*Foldable (F)*	*3.41 – 4.20*	*Attractively Dispersed Evenly (ADE)*
2.61 – 3.40	*Moderately Foldable (MF)*	*2.61 – 3.40*	*Dispersed Evenly (DE)*
1.81 – 2.60	*Less Foldable (LF)*	*1.81 – 2.60*	*Slightly Attractively Dispersed Evenly (SADE)*
1.0 – 1.80	*Not Foldable (NF)*	*1.0 – 1.80*	*Not Attractively Dispersed Evenly (NADE)*

Scale	*Verbal Interpretation (VI) in Opacity*
4.21 – 5.00	*Very Translucent (VT)*
3.41 – 4.20	*Translucent (T)*
2.61 – 3.40	*Moderately Translucent (MT)*
1.81 – 2.60	*Less Translucent (LT)*
1.0 – 1.80	*Not Translucent (NT)*

Difference in Appearance, Texture, Foldability, Fiber Dispersion, and Opacity of Paper from Calamondin Pulp Using Green Binders

Table 4 shows that there was no significant difference between the Appearance and the Fiber Dispersion, and there was a significant difference among the texture, foldability and opacity in the acceptability of calamondin handmade paper.

Results of the analysis of variance (ANOVA) revealed varying levels of significance across the evaluated sensory qualities of the novelty/decorative handmade paper made from calamondin fruit residue with green binders. For appearance, the F-value was .171 with a p-value of .843. Since the p-value is greater than the standard significance level of 0.05, this simply means that there were no statistically significant differences in appearance among the three treatments.

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For the texture, the F-value was 6.288 with a p-value of .002. Since the p-value is less than the standard significance level of 0.05, this indicates that there were statistically significant differences in texture among the three treatments.
For the foldability, the F-value was 8.422 with a p-value of .000. Since the p-value is less than the standard significance level of 0.05, this indicates that there were statistically significant differences in foldability among the three treatments.

For the fiber dispersion, the F-value was .872 with a p-value of .420. Since the p-value is greater than the standard significance level of 0.05, this indicates that there were no statistically significant differences in foldability among the three treatments.

Lastly, for the opacity the F-value was 45.739 with a p-value of .000. Since the p-value is less than the standard significance level of 0.05, this indicates that there were statistically significant differences in foldability among the three treatments.

Thus, findings on the acceptability of the product revealed no significant difference in appearance and fiber dispersion, while there was a significant difference in texture, foldability, and opacity.

The findings which present the analysis of variance (ANOVA) for the sensory qualities of novelty/decorative handmade paper made from calamondin fruit residue with green binders, are consistent with similar studies examining the influence of different treatments on paper properties. Irregular and tactile are the usual texture of handmade papers. Infused with distinct fibers incorporated with other materials makes handmade paper possess aesthetic appeal. Variations in opacity, thickness, and surface finish contribute to its uniqueness, turning each sheet an artwork. Factors such as fiber type, pressing techniques, and sheet formation may affect the durability and strength of handmade paper but its natural beauty depends in its flaws and innate character (Saini, 2024).

The Finding revealed that the appearance and fiber dispersion had similarity in all treatments. The texture of the calamondin fruit handmade paper have the frequency of 6.288 and its significance is .002. The Foldability have the frequency of 8.422 and its significant difference of .000. the Opacity have the frequency of 45.739 and has the significant difference of .000.

Thus, the data proved that the null hypothesis was accepted in terms of appearance and fiber dispersion. However, the results showed that the texture, foldability, and opacity exhibited a significant difference pertaining physical characteristics of the products, therefore, the null hypothesis was rejected.

Table 4. Differences in appearance, texture, foldability, fiber dispersion, and opacity of paper from calamondin pulp using green binders.

Physical Characteristics	Sum of Squares	df	Mean square	F-value	P-value	Remarks
	.173	2	.087	.171	.843	
Appearance	74.660	147	.508			ns
	74.833	149				
	9.693	2	4.847	6.288	.002	s
Texture	113.300	147	.771			
	122.993	149				
	14.440	2	7.220	8.422	.000	s
Foldability	126.020	147	.857			
	140.460	149				
Fiber Dispersion	1.213	2	.607	.872	.420	ns
	102.260	147	.696			
	103.473	149				
	42.453	2	21.227	45.739	.000	s
Opacity	68.220	147	.464			
	110.673	149				

Legend: Level of significance = 0.05; s = significant

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Acceptability of Paper from Calamondin Fruit Pulp

Table 5 has covered acceptability of paper from calamondin pulp in terms of appearance, texture, foldability, fiber dispersion, and opacity. In terms of appearance, Treatment B (calamondin fruit pulp with taro runners pulp) got the highest mean of 4.4 and verbally interpreted as of "Very Acceptable". Followed by Treatment A (calamondin fruit pulp with malabar spinach stems pulp) with the mean score of 4.38 with the verbal interpretation of "Very Acceptable". And Treatment C (calamondin fruit pulp with okra fruit pulp) verbally interpreted of "Very Acceptable" with a mean score of 4.32.

In terms of Texture, Treatment A (calamondin fruit pulp with malabar spinach stems pulp) got the highest mean score of 4.32 with the verbal interpretation of "Very Acceptable". Followed by Treatment B (calamondin fruit pulp with taro runners pulp) with the mean score of 3.96 with the verbal interpretation of "Acceptable". And Treatment C (calamondin fruit pulp with okra fruit pulp) with mean score of 3.70 and verbally interpreted as "Acceptable".

In terms of Foldability, Treatment A (calamondin fruit pulp with malabar spinach stems pulp) got the highest mean score of 4.32 with the verbal interpretation of "Very Acceptable". Followed by Treatment B (calamondin fruit pulp with taro runners pulp) with the mean score of 3.94 with the verbal interpretation of "Acceptable". And Treatment C (calamondin fruit pulp with okra fruit pulp) with mean score of 3.56 and interpretated as "Acceptable".

In terms of Fiber Dispersion, Treatment A (calamondin fruit pulp with malabar spinach stems pulp) got the highest mean score of 4.26 with the verbal interpretation of "Very Acceptable". Followed by Treatment B (calamondin fruit pulp with taro runners pulp) with the mean score of 4.16 with the verbal interpretation of "Acceptable". And Treatment C (calamondin fruit pulp with okra fruit pulp) with the mean score of 4.04 with the verbal interpretation of "Acceptable".

In terms of Opacity, Treatment A (calamondin fruit pulp with malabar spinach stems pulp) got the highest mean score of 4.70 with the verbal interpretation of "Very Acceptable". Followed by Treatment B (calamondin fruit pulp with taro runners pulp) with the mean score of 3.66 with the verbal interpretation of "Acceptable". And Treatment C (calamondin fruit pulp with okra fruit pulp) with the mean score of 3.50 with the verbal interpretation of "Acceptable". In overall, Treatment A (calamondin fruit pulp with malabar spinach stems pulp) has the highest score mean of 4.40 and verbally interpreted as "Very Acceptable".

This indicates that Treatment A (calamondin fruit pulp with malabar spinach stems pulp) is the most translucent of all the treatments. Next is the Treatment B (calamondin fruit pulp with taro runners pulp) with the mean score of 4.02 and verbally interpreted as "Acceptable". And Treatment C (calamondin fruit pulp with okra fruit pulp) has the lowest mean score of 3.82 and verbally interpreted as "Acceptable".

According to Membranes (2023), fibers from plants, is known to be a good source of raw materials for paper production to minimize problems in deforestation which corresponds with the goal of calamondin handmade paper with green binders in producing environmentally friendly products. Furthermore, the results of the data can be aligned with the prior research of Reynolds (2025), stating that handmade paper burst with uniqueness.

Each sheet reflected the artist's vision, with subtle variations in color, texture and thickness. It also implied that the raw materials used such as calamondin fruit residues, malabar spinach stems, taro runners, and okra fruit really has the potential of being a renewable source of energy. As aligned also to the work of Favini as cited by Bowles (2025), by embracing eco-innovative raw materials, offsetting emissions, and championing renewable energy, this handmade paper from calamondin with green binders leads the way towards a more environmentally conscious paper industry, setting an inspiring example for others to follow.

Lastly, according to Saini (2024), handmade paper exceeds in terms of creativity and uniqueness, granting an artist exceptional masterpiece. Its aesthetic appeal and tactile qualities looked up by designers, artists and enthusiasts who gave importance to authenticity and craftsmanship.

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Table 4. Acceptability of paper from calamansi pulp in terms of appearance, texture, foldability, fiber dispersion, and opacity.

Treatments	Appearance **Mean**	Texture **Mean**	Foldability **Mean**	Fiber Dispersion **Mean**	Opacity **Mean**	Over-all Mean	Quality Description
Treatment A (Calamondin fruit pulp 500g, malabar spinach stems pulp 387g, water 10 L)	4.38	4.32	4.32	4.26	4.70	4.40	**Very Acceptable**
Treatment B (Calamondin fruit pulp 500g, taro runners pulp 500g, water 10 L)	4.4	3.96	3.94	4.16	3.66	4.02	**Acceptable**
Treatment C (Calamondin fruit pulp 500g, okra fruit pulp 500g, water 10 L)	4.32	3.70	3.56	4.04	3.50	3.82	**Acceptable**

Legend: ***Adjectival Description (AD)***

Scale	*Verbal Interpretation*
4..21 – 5.00	*Very Acceptable*
3.41 – 4.20	*Acceptable*
2.61 – 3.40	*Moderately Acceptable*
1.81 – 2.60	*Less Acceptable*
1.0 – 1.80	*Not Acceptable*

IV. CONCLUSION

Based on the findings, the following generalization were drawn. Three treatments of calamondin handmade paper were formulated and evaluated by the panelists. Treatment A (calamondin fruit pulp 500g with malabar spinach stems pulp 387g), Treatment B (calamondin fruit pulp 500g with taro runners pulp 500g), and Treatment C (calamondin fruit pulp 500 g with okra fruit pulp 500g).

Based on the results of the sensory qualities in the physical characteristics of paper from calamondin fruit pulp, among the three green binders, malabar spinach stems pulp binder got the highest results in most of the quality attributes except for the appearance which the taro runners pulp binder got the highest score. In terms of texture, foldability, fiber dispersion, and opacity taro runners pulp binder got the second highest results. And lastly, across all the sensory factors, the okra fruit pulp binder got the third place.

Findings on significant difference in appearance, texture, foldability, fiber dispersion, and opacity of the paper from calamondin pulp using green binders revealed that there was no significant difference in appearance and fiber dispersion among the three treatments, while there was a significant difference in texture, foldability, and opacity across the three treatments. The results implied that the null hypothesis was accepted in terms of appearance and fiber dispersion. However, in terms of texture, foldability, and opacity, it was stating that there was a significant difference in the physical characteristics of the products, therefore, the null hypothesis was rejected.

The results in the collected data on the acceptability of paper from calamondin fruit pulp indicated that the Malabar spinach stems pulp (Treatment A) was the best binder for the calamondin handmade paper among the green binders (treatments) tested and was considered as “Very Acceptable” by the evaluators.

The results indicated that each treatment significantly influences the quality result of calamondin handmade paper in terms of appearance, texture, foldability, fiber dispersion, and opacity. These findings provided valuable understanding into the efficacy and performance of different treatments, guiding artists and researchers in their selection and application of materials for handmade paper making.

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REFERENCES

[1]. Alaban, C. A., Alaban, M. A. C., Former Handmade Paper Making Manufacturers, Sitio Kabulakan, Brgy. Cogon, Roxas City, Capiz

[2]. Bhandari, P. Nikolopoulou, K., Likert Scale, https://www.scribbr.com/methodology/likert-scale/

[3]. Capinera, J. L., Okra, https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/okra

[4]. De Chiron, D.R., Handmade Paper Production with the Use of Forest and Agricultural Waste De Dios Mulato, https://www.academia.edu/33046935/HANDMADE_PAPER_PRODUCTION_WITH_THE_USE_OF_FORESTAND_AGRICULTURAL _WASTE_DE_DIOS_MULATO

[5]. De Dios, D. R., Mulato, R. D. C., Handmade Paper Production with the Use of Forest and Agricultural Waste,https://www.academia.edu/33046935/HANDMADE_PAPER_PRODUCTION_WITH_THE_USE_OF_FOREST_AND_AGRICULTURAL_WASTE_DE_DIOS_MULATO. Retrieved date February 15, 2023.

[6].Dylan, M., Orange is the New Paper – The Story of the Crush Citrus Paper, https://www.paperpapers.com/news/orange-is-the-new-paper-the-story-ofthecrushcitruspaper/?srsltid=AfmBOooHz61e4RVgU46P0sqMT2LOA7UlhxzKRagIhtX3EiOGZ58EUFAQ%20Mark%20Dylan

[7]. Favini, Crush Story: from citrus fruit to paper, https://www.favini.com/en/news/crush-story-from-citrus-fruit-to paper/, © Copyright 2025 FAVINI srl P.I 03464230246

[8]. Flory, A. R., et al., Development of a Green Binder System for Paper products, https://b2b.sigmaaldrich.com/PH/en/techdocs/paper/313488,PMCID: PMC364441, DOI: 10.1186/1472-6750-13-28. Retrieved date May 21, 2024.

[9]. Hiebert, Helen, Finding Plant Fibers, https://www.handpapermaking.org/post/finding-plant-fibers. Retrieved date May 21, 2024.

[10]. Ibrahim, A., Definition Purpose and Procedure of Developmental Research: An Analytical Review, ttps://www.researchgate.net/publication/312934049_Definition_Purpose_and_Procedure_of_Developmental_Research_An_Analytical_Review, Retrieved date January 2016

[11]. Jain, P., Gupta, C., A Sustainable Journey of Handmade Paper from Past to Present: A Review, Problemy Ekorozwoju – Problems of Sustainable Development 2021, 16(2), 234-244 Doi: 10.35784/Pe.2021.2.25. Retrieved date February 15, 2023.

[12]. Jang, Y, A paper cup including pulp of citrus peel, https://patents.google.com/patent/ KR20200054438A/en

[13]. Johnny S., Tuquero, J., Acosta, M., Malabar Spinach (Basella alba), Cooperative Extension & Outreach, College of Natural & Applied Sciences, University of Guam, Funded by Western SARE grant number RGR20-003, https://www.uog.edu/_resources/ files/extension/publications/Malabar_Spinach_30_12_21.pdf

[14]. Jordan, Jacobs H., Easson, Michael W., Cheng, Huai N., and Condon, Brian D., Application of Lignin-Containing Cellulose Nanofibers and Cottonseed Protein Isolate for Improved Performance of Paper, https://pubmed.ncbi.nlm.nih.gov /35683825/, PMCID: PMC9183002 DOI: 10.3390/polym14112154. Retrieved date May 21, 2024.

[15]. Kim, H. G., Paper containing citrus foil fibers, https://patents.google.com/patent/ KR100669109B1/en, Patent KR100669109B1. Retrieved date February 15, 2023.

[16]. Kim, H. G, Paper Comprising Fiber of Citrus Peel, International Publication Number WO2008016210A1, https://patentscope.wipo.int/search/en/detail.jsf?docId=KR11 82890&_cid=P11-L4Y171-07912-1

[17]. Levobitz, D., Nonreactive Cookware, https://www.davidlebovitz.com/what-is-nonreactive-reactive-cookware/

[18]. Maldonado, R., M., Rojas, G. A., Romero, B. A, Maldonado, M. P., Salinas, D. V., Hernandez, E. C. (2021), Morphological characteristics of okra fruits [Abelmoschus esculentus (L.) Moench.] cultivated in the dry tropic, https://doi.org/ 10.32854/agrop.v14i2.1967.

[19]. Micabanes, I. G. T., et al. (March 2020), Gabi (Colocasia esculenta taro) Stem and Leaves as Decorative Paper, Misamis Occidental National High School, Oroquieta City, cribd.com/document/486468139/Gabi-Colocasia-esculenta-taro-Stem-and-Leaves -as-Decorative-Paper

[20]. Srean, P., Charoenphun, N., Venkatachalam, K., Yuvanatemiya, V., Phytochemicals, Bioactive Properties and Commercial Potential of Calamondin (Citrofortunella microcarpa) Fruits: A Review, https://www.researchgate.net/publication/69960670_Phytochemicals_Bioactive_Properties_and_Commercial_Potential_of_Calamondin_Citrofortunella_microcarpa_Fruits_A_Review

[21]. Saini, J., How Does Handmade Paper Differ from Machinemade Paper in Terms of Qualtity and Characteriatics, Alpana Papers, alpanapapers.com/blog-how-does-handmade-paper-differ-from-machinemade-paper-in-terms-of-qualityandcharacter istics -386f9a0fe53997dc

[22]. Sannapapamma K.J., Mariyappanavar S., Sangannavar V.V., Jamadar D., Vastrad J.V. and Byadagi S. A., Development and Quality Assessment of Handmade Papers Using Underutilized Agro Based Natural Fibres, https://www.phytojournal.com/archives/ 2020/vol9issue2/PartW/9-2-86-771.pdf

DOI: 10.17148/IARJSET.2025.12636

[23]. Tokens, E., What is Non-Woven Interfacing, https://www.thecreativecurator.com/what-is-non-woven-interfacing/

[24]. Bachmann, K., The Treatment of Transparent Papers: a Review, https://cool. culturalheritage.org/coolaic/sg/bpg/annual/v02/bp02-02.html

[25]. Quijano, M. F., Quijano, G., Diaz, R., Agricultural economic production of Philippine calamansi industry: A basis for production local development plan., https:// journals.epalli.com/home/index.php/ajmr., DOI: https://doi.org/10.54536/ajmri.v2 i4.1862,

[26]. Quillen, K. (January 2022), How to Make Paper from Plants, Mother Earth News, https://www.motherearthnews.com/diy/making-paper-from-plants-zm0z17jjzqui/#:~:text=Iris%20leaves%20and%20lily%20leaves,plant%20to%20ensure%20continued%20growth

[27]. Zou, Y., Zhang, H., Zheng, L., Physiocochemical Characteristics of Calamondin (Citrus macrocarpa) from Hainan), Asian Agricultureal Research 2020, 12(12); 58-62, DOI: 10.19601/j.cnki.issn1943-9903.2020.12.014