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Development of Watercolor Paint Made from Plant Pigments

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Abstract—**This study focused on the development and evaluation of watercolor samples derived from alternative materials. It aimed to identify the physical characteristics of the developed watercolors, including color temperature (warm or cool) and lightfastness (fugitive or non-fugitive). The study also evaluated the quality of the samples using a four-point Likert scale, focusing on granulation, staining, transparency, and pigment number, and sought to determine any significant differences between the developed samples and commercially available control samples. An experimental research design was employed, and data were gathered from artists, Drafting Technology students, and faculty members from the College of Industrial Technology. The results were analyzed using mean, standard deviation, and ANOVA (Analysis of Variance). Findings revealed that all red, yellow, and blue treatments exhibited cool shades, whereas control yellow samples showed warm tones. In terms of lightfastness, all developed colors were rated as semi-fugitive. For granulation, red treatments were rated as semi-granulating, while yellow and blue treatments were non-granulating. Regarding staining, RT50 red was classified as staining, and RT25 and RT75 as highly staining; yellow and blue treatments were also rated as highly staining. All color treatments were rated opaque in terms of transparency. As for pigment composition, RT50 was identified as containing triple pigments, while the others contained multiple pigments. ANOVA results showed significant differences between the developed and control samples. In red color samples, granulation, staining, and pigment number showed significant differences, while transparency did not. For yellow and blue samples, granulation and pigment number were also found to be significantly different, while staining and transparency were not. These findings suggest that the developed watercolor samples, despite being derived from alternative materials, exhibit characteristics and performance comparable to those of commercial watercolors, supporting their potential use in creative and technical applications.**

Index Terms—**Plant pigments, beetroots, turmeric, blue ternate, watercolor, College of Industrial Technology, Marinduque State University.**

1. Introduction

Plants have long been used as a source of color and fragrance. Local plants, in particular, offer a readily available and cost-effective option for natural colorants. Various plant parts, including stems, leaves, fruits, seeds, and pills, can be used to extract natural pigments. More than 500 plant species have been identified as potential sources of dyes (Vezrma, 2017).

The Philippines boasts a diverse range of plants that can be utilized for natural coloring. These plants not only provide vibrant hues but also offer a range of unique colors. Beetroot, known for its bright red to bluish-red color, is a common source of red pigment. Turmeric, another popular choice, is prized for its yellow color, which comes from the polyphenol curcumin. Butterfly pea, with its vibrant blue flowers, is also an excellent source of natural pigment.

Watercolor, a popular painting medium, consists of pigment dissolved in water and bound by a gum or similar agent. Its advantages include ease of application, transparency, color brilliance, and affordability. The primary components of watercolor paint are colorant, binder, additives, and solvent.

Natural dyes offer several advantages over synthetic dyes. They are biodegradable, non-toxic, hypoallergenic, and non-carcinogenic. Additionally, natural dyes are readily available and renewable, making them a more sustainable option. The use of synthetic dyes can lead to environmental pollution, health hazards, and ecological imbalances. In contrast, natural dyes are eco-friendly and pose no risk to human health. They are widely used in various industries, including confectionery, textiles, cosmetics, medicines, leather, paper, paint, ink, and more. Natural dyes have been an integral part of human life for centuries due to their non-toxic and biodegradable nature. The environmental and health concerns associated with synthetic dyes have highlighted the importance of natural alternatives. In recent studies, researchers have successfully extracted dyes from plants, such as Torenia, by crushing the flowers with water and optimizing factors including temperature, pH, and extraction time.

Given the wide variety of plant colors available, plant-based pigments offer significant potential for promoting sustainable, environmentally friendly watercolor production. Thus, the researchers decided to develop an alternative watercolor using plant pigments due to their non-toxic, eco-friendly properties. Watercolor paints consist of pigments held together by a water-soluble binder, along with additives and solvents that help stabilize the mixture.

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In light of this, the study focused on developing an alternative to watercolor paste derived from plant pigments. Specifically, this study aimed to:

1. Identify the physical characteristics of the developed watercolor samples in terms of:
   1.1. color classification (warm and cool) and
   1.2. lightfastness rating (non-fugitive and fugitive);
2. Evaluate the quality of the developed watercolor samples using a four-point Likert scale in terms of:
   2.1. granulation,
   2.2. staining,
   2.3. transparency, and
   2.4. pigment number; and
3. Ascertain any significant differences in the evaluated quality of the developed watercolor in comparison with control samples.

2. Methodology

A. Research Design

This study employed an experimental design to determine how a specific factor (the independent variable) influences another factor (the dependent variable). In this method, conditions were carefully controlled, and data were systematically collected to draw accurate conclusions about the research hypothesis.

This study focused on developing an alternative watercolor paint made from plant pigments. The researchers selected the primary colors (red, yellow, and blue) to guide the formulation of the alternative watercolor. Beetroot *(Beta vulgaris L.)* was used as the source of red pigment, butterfly pea or blue ternate *(Clitoria ternatea)* for blue pigment, and turmeric *(Curcuma longa)* for yellow pigment. These plants were chosen as raw materials for developing the watercolor due to their availability and their strong natural pigmentation, which is suitable for producing primary colors.

A solid watercolor/pallet watercolor was developed for this purpose. The binder materials included gum arabic powder, glycerin, clove oil, and distilled water. Gum Arabic powder, made from the solidified sap of thorny, shrubby acacia trees (*Acacia arabica* or *Acacia senegal)*, acts as an extender, increasing paint viscosity and allowing the pigment to sit on the paper surface rather than being fully absorbed, resulting in a longer drying time. Glycerin served as a moistening and plasticizing agent, making the paint more flexible and less prone to cracking. It is also a humectant that helps to regulate moisture content and prevent excessive drying.

Clove oil was used as a preservative because of its active ingredient, eugenol, which has antibacterial and antifungal properties. These properties help inhibit microbial growth and prevent mold formation, thereby extending the shelf life of the watercolor. Distilled water (hot) was used to dissolve and combine all the binder ingredients.

In developing the watercolor samples, multiple treatments were prepared. Each color had three treatment levels. For the red pigment (beetroot), the treatments were RT25 (25% pigment, 75% binder), RT50 (50% pigment, 50% binder), and RT75 (75% pigment, 25% binder). For the blue pigment (Clitoria ternatea), the treatments were BT25, BT50, and BT75, with the same pigment-to-binder ratio for each. Similarly, for the yellow pigment (turmeric), the treatments were YT25, YT50, and YT75. The developed watercolor samples were compared with two control samples to validate the experimental results and assess the effectiveness of the alternative watercolor formulations.

B. Participants and Sampling Technique

Using Purposive Sampling, 30 expert respondents evaluated the developed watercolor samples. They evaluated the samples' quality with respect to granulation, staining, transparency, and pigment. The evaluation aimed to identify strengths and areas for improvement in the developed products, thereby enhancing suitability for their intended purpose and providing a foundation for their potential future development.

C. Research Instrument

This evaluation tool was designed to determine the quality and characteristics of the developed samples. A Four-Point Likert Scale was used to rate the evaluation.

D. Data Gathering Procedure

This section shows the entire research process and data gathering procedures.

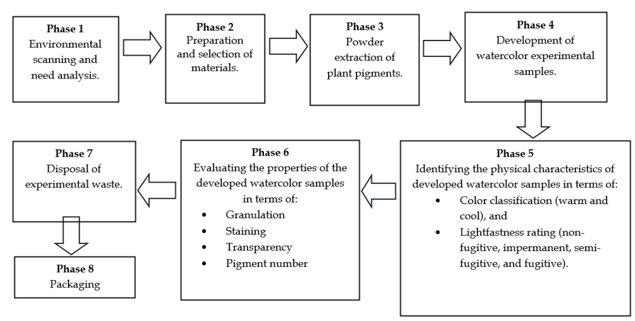


Fig. 1. Process in making alternative watercolor

E. Data Analysis Procedure

The researchers used appropriate statistical formulas and consulted a statistician to analyze the gathered data. Descriptive statistics, such as measures of central tendency (mean) and measures of variability (standard deviation), were employed. Inferential statistics, including the parametric test F-test or Analysis of Variance (ANOVA), as well as Post Hoc Analysis using Tukey's Honestly Significant Difference (HSD) test, were also utilized.

The mean and standard deviation were used to identify the ratings of the developed watercolor samples and control samples in terms of granulation, staining, transparency, and pigment number. The F-test or ANOVA was applied to determine whether there were significant differences in the evaluated quality of the developed watercolors compared with the control samples. Tukey's HSD test was used to identify significant differences between individual samples, including the control samples, and to determine which samples exhibited higher levels of significant difference.

Table 1
Product evaluation tools

Scale	Scale Range	Indicator/Description	Verbal Interpretation	Verbal Description
Granulation Rating: This characteristic represents the texture and appearance of the developed watercolor. This characteristic is composed of the following sub-characteristics:				
Scale	**Scale Range**	**Indicator/Description**	**Verbal Interpretation**	**Verbal Description**
4	3.25-4.00	Non-granulating - A non-granulating is smooth, even watercolor has fine consistency and flows evenly over the paper.	Excellent	Smoothness of 76% to 100%
3	2.50-3.24	Semi-granulating - Slightly fine and smooth textures.	Very Good	Smoothness of 51% to 75%
2	1.75-2.49	Granulating - Granulating watercolors produce slightly delicate textures.	Good	Smoothness of 26% to 50%
1	1.00-1.74	Highly-granulating - A highly granulating watercolor creates highly uneven mottled washes, delicate textures, and has a grain-like particle on the surface of the paper.	Poor	Smoothness of 0% to 25%
Staining: This characteristic represents the staining rating of the developed watercolor. This characteristic is composed of the following sub-characteristics				
Scale	**Scale Range**	**Indicator/Description**	**Verbal Interpretation**	**Verbal Description**
4	3.25-4.00	Highly staining - Highly staining watercolor will leave a permanent mark on the paper.	Excellent	Highly-staining possesses 76% to 100% pigmentation
3	2.50-3.24	Staining - Staining watercolor means once the paint is dry on paper, it is difficult or almost impossible to lift or remove.	Very Good	Staining possesses 51% to 75% pigmentation
2	1.75-2.49	Semi-staining - Semi-staining colors can still be lifted off but will leave a hint of color.	Good	Semi-staining possesses 26% to 50% pigmentation
1	1.00-1.74	Non-staining - non-staining colors do not have stains at all.	Poor	Non-staining possesses 0% to 25% pigmentation.
Transparency: This characteristic represents the transparency and opacity of the developed watercolor. This characteristic is composed of the following sub-characteristics				
Scale	**Scale Range**	**Indicator/Description**	**Verbal Interpretation**	**Verbal Description**
4	3.25-4.00	Opaque- Opaque blocks the light from shining through, so it looks thicker and somewhat cloudy.	Excellent	Pigmentation of 76% to 100%
3	2.50-3.24	Semi-opaque- Semi-opaque which reflects most of the light but lets a small amount through.	Very Good	Pigmentation of 51% to 75%
2	1.75-2.49	Semi-transparent- Imperfectly or almost transparent which lets most of the light through but reflects a small part.	Good	Pigmentation of 26% to 50%
1	1.00-1.74	Transparent- A transparent watercolor allows the light to come through and reflect from the white paper, which makes the color glow.	Poor	Pigmentation of 0% to 25%
Pigment Number: This characteristic represents the number of pigments produced by a watercolor. This characteristic is composed of the following sub-characteristics				
Scale	**Scale Range**	**Indicator/ Description**	**Verbal Interpretation**	**Verbal Description**
4	3.25-4.00	Multiple Pigments	Excellent	Multiple Pigment produced more than three colors
3	2.50-3.24	Triple Pigments	Very Good	Triple Pigments produced three (3) colors
2	1.75-2.49	Double Pigments	Good	Double Pigment produced two (2) pigments
1	1.00-1.74	Single Pigment	Poor	Single Pigment produced only one (1) pigment

The p-value served as the basis for determining statistical significance. A p-value of 0.05 or lower indicates a statistically significant result, while a p-value greater than 0.05 indicates that the result is not statistically significant.

F. Ethical Considerations

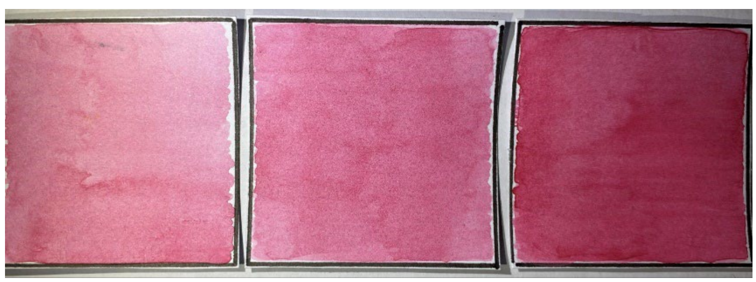
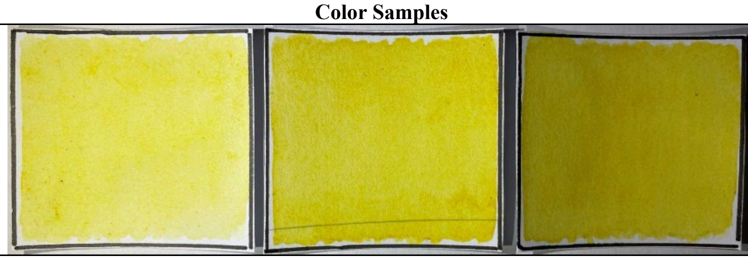
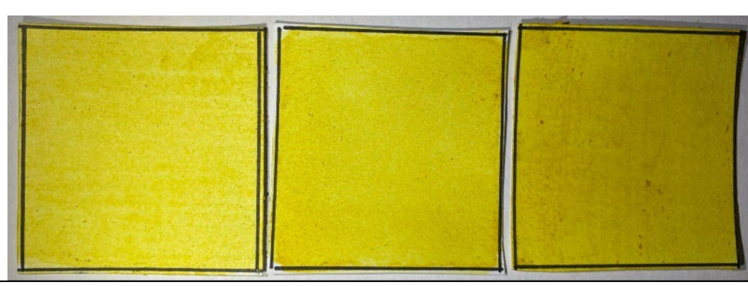
The researchers ensured that the conduct of the study adhered to ethical standards of research. Prior to data collection, the objectives and procedures of the study were clearly explained to the respondents. Informed consent was obtained, and participation is voluntary. Respondents were given the freedom to withdraw at any stage of the research without penalty. Confidentiality of the respondents' information was strictly maintained. Codes or numbers were used instead of names to protect identities. The data gathered were solely used for academic purposes and not disclosed to any third party. Furthermore, the researchers ensured that the product tested posed no harm or risk to participants. Proper safety guidelines were observed during the testing process.

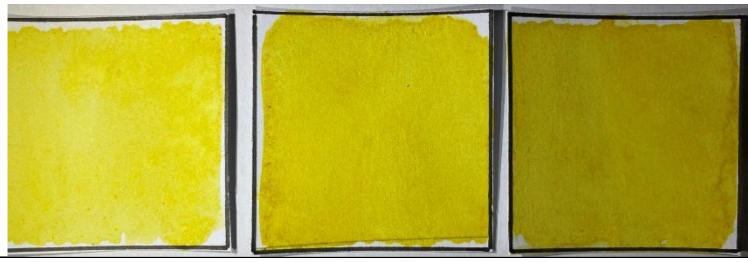
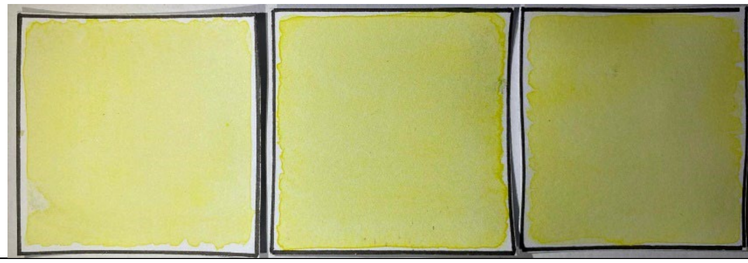
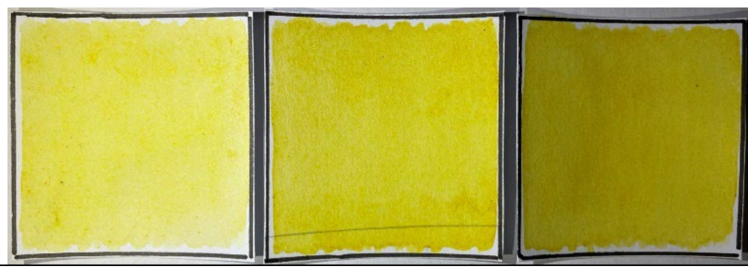
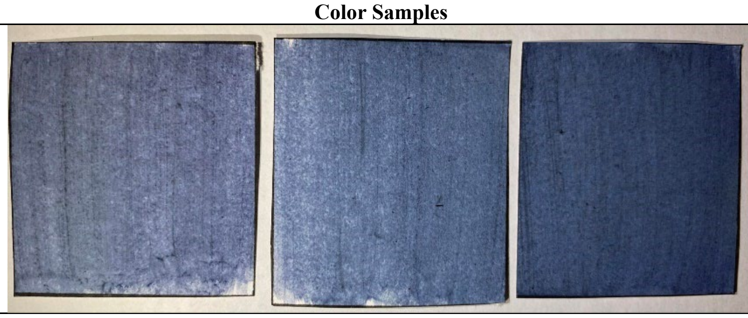
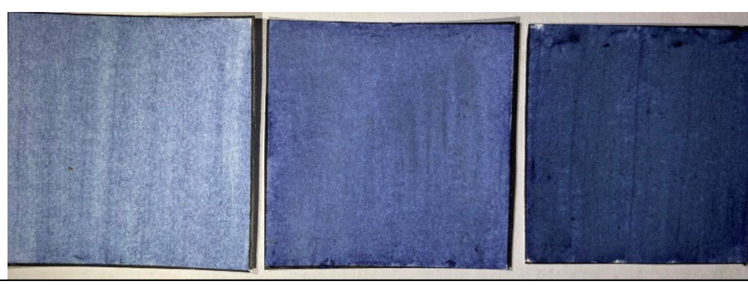
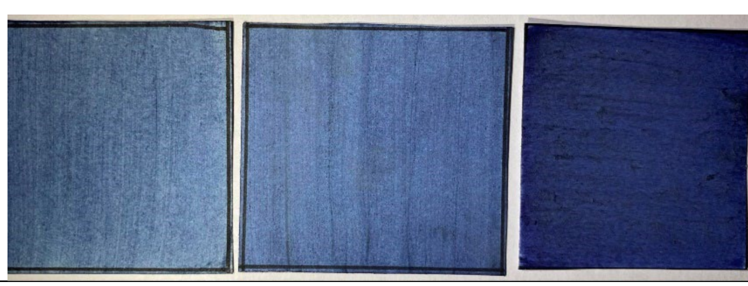
3. Results and Discussion

A. Physical Characteristics of Developed Watercolor Samples

The developed watercolor samples were subjected to observation and testing to identify the specific colors as warm and cool using the color wheel. Moreover, the lightfastness rating of the samples as non-fugitive and fugitive were also identified in this study. Table 2 presents the identified color of all the samples.

Table 2
The cool and warm color of developed watercolor samples in terms of red, yellow, and blue colors

	Red Color (Beetroots)	
Treatment	**Color Samples**	**Classification**
RT25		Cool Red
RT50		Cool Red
RT75		Cool Red
RC2		Cool Red
	Yellow Color (Turmeric)	
Treatment	**Color Samples**	**Classification**
YT25		Warm Yellow
YT50		Warm Yellow

YT75		Warm Yellow
YC1		Warm Yellow
YC2		Warm Yellow
	Blue Color (Blue Ternate)	
Treatment	**Color Samples**	**Classification**
B25		Warm Blue
BT50		Warm Blue
BT75		Warm Blue

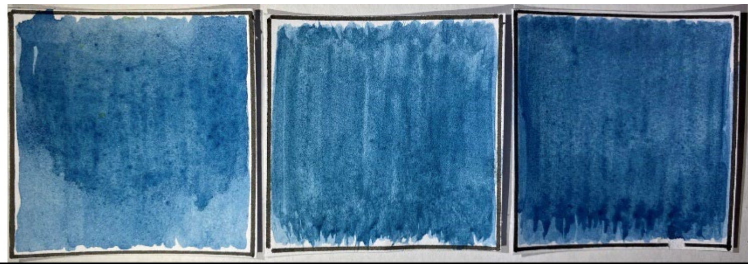
BC1		Warm Blue
BC2		Warm Blue

Table 2 shows the specific colors classified as warm and cool with reference to the color wheel. According to the color wheel interpretation of colors, the three sample treatments and control samples in the red color category were identified as cool colors. In describing color, the researchers referred to the color as “bias”. A red may exhibit either a yellow bias or a blue bias. Consistent with the three sample treatments, the red pigments displayed a blue bias, indicating a cool color. The treatments were also matched with cool red hues on the color wheel. These results indicate that the different treatments applied did not affect the color classification.

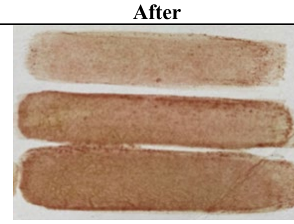
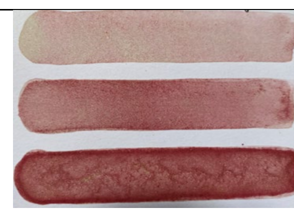
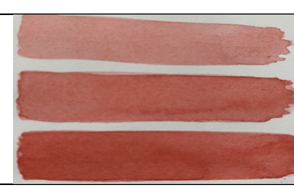
This finding aligns with a study on industrial use of beetroot powder or extracted pigments to enhance red coloration in various food products, such as tomato paste, sauces, soups, desserts, jams, jellies, ice creams, sweets, and breakfast cereals (Roy & Koul, 2004). Red beetroot *(Beta vulgaris L.)* is a natural source of red pigment known as betalains, which consist of betacyanins (red) and betaxanthins (yellow). Betanin, the primary betacyanin in beetroot, constitutes 75-95% of its red pigment (Von Elbe, 1972).

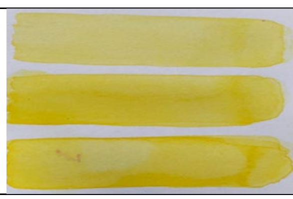
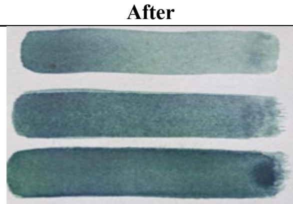
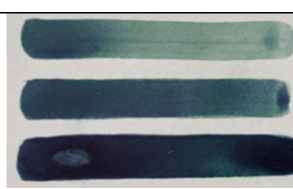
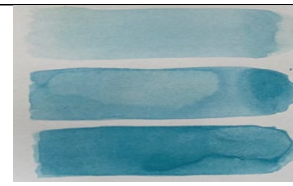
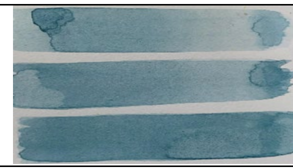
The three sample treatments and control samples in yellow color category were classified as warm colors. The researchers described yellow hues using a color "bias," such as "greenish yellow" to indicate a green bias. When compared to the color wheel, the treatments showed no significant effect on the classification of yellow as a warm color. Turmeric, derived from its rhizome, is a natural source of warm golden pigment widely used for dyeing natural cotton, silk, and wool (Sarkar, 2022).

Similarly, the three sample treatments and control samples in the blue color category were identified as cool colors. A cool blue with a green bias was described as "greenish blue," while a warm blue with a purple bias was referred to as "bluish purple." The treatments did not alter the classification of blue in terms of warm or cool color interpretation. The blue pea flower is a rich source of blue pigment containing anthocyanins responsible for its vibrant coloration. Its petals are high in polyacylated anthocyanins known as ternatins, which exhibit unique color-changing properties (Jeyaraj, 2022).

Relevant to the identified color characteristics of the produced samples, Table 3 presents the lightfastness rating of all the samples after one month of observation.

Table 3
Lightfastness of the watercolor samples

Red Color (Beetroots)		
Treatments	**After**	**Classification**
RT25		Semi-fugitive
RT50		Non-fugitive
RT75		Semi-fugitive
RC1		Non-fugitive
RC2		Non-fugitive

Yellow Color (Turmeric)		
Treatments	**After**	**Classification**
YT25		Impermanent
YT50		Non-fugitive
YT75		Impermanent
YC1		Non-fugitive
YC2		Non-fugitive
Blue Color (Blue Ternate)		
Treatments	**After**	**Classification**
BT25		Impermanent
BT50		Non-fugitive
BT75		Impermanent
BC1		Non-fugitive
BC2		Non-fugitive

Based on the testing and one-month observations of the developed watercolor samples, red color with 25% and 75% concentrations were rated as "semi-fugitive," while the 50% treatment was rated as "non-fugitive". This indicates that the beetroot pigment was affected by the different treatments applied. Observation during the development process suggests that the 50% treatment had a balanced mixture of binder and pigment, resulting in greater color stability. In contrast, the 25% treatment contained more binder but less pigment, which may have contributed to fading due to insufficient pigment concentration. Meanwhile, the 75% treatment contained a higher pigment concentration but less binder, which may have resulted in fading due to inadequate preservation. The binder, particularly glycerin, acts as a preservative that helps maintain the color stability of watercolors. This explains why the 50% treatment showed no signs of fading. These findings indicate that the beetroot pigment is sensitive to lightfastness. Both red control samples were rated as "non-fugitive," as no fading was observed after one month.

For the yellow color samples, the 25% and 75% treatments were rated as "impermanent" due to slight signs of fading, while the 50% treatment was rated as "non-fugitive." Similar to the red samples, treatment proportions affected the lightfastness of the yellow watercolor. The yellow control samples were also rated as "non-fugitive," showing no signs of fading.

In the blue color samples, the 25% and 75% treatments were rated as "impermanent" due to slight signs of fading, while the 50% treatment was rated as "non-fugitive." As with the red and yellow samples, the treatment proportions influenced lightfastness. Both blue control samples exhibited no fading and were rated as "non-fugitive."

In summary, the 50% pigment treatment consistently achieved a "non-fugitive" rating, while the 25% and 75% treatments were rated as "semi-fugitive." These results indicate that lightfastness is influenced more by the binder-to-pigment ratio than by pigment concentration alone.

Colak (2015) investigated the color stability of beetroot (Beta vulgaris) extract used as a wood stain under ultraviolet light irradiation. The extract was prepared using ultrasonic-assisted extraction and combined with various mordant mixtures. Different wood species, including Scots pine, oriental beech, oak, and walnut, were treated and exposed to UV light for varying durations. The findings showed that wood specimens stained with beetroot extract exhibited superior color stability compared to those stained with synthetic dyes, suggesting its potential as a sustainable and environmentally friendly alternative, particularly for indoor applications and toys.

Natural dyes derived from plants and animals are generally considered safe and non-toxic, making them attractive substitutes for synthetic dyes, especially in the food industry (Leong, 2018). However, their higher cost and lower stability may limit widespread application (Ravichandran, 2018).

Turmeric is considered a fugitive dye and exhibits poor wash and light fastness due to the phenolic groups in curcumin, which react with soda ash during washing (Sarkar, 2022). Mordanting improves both wash and light fastness by reducing the chromophore's susceptibility to photochemical oxidation, although it may slightly reduce rubbing fastness.

The colorfastness of Clitoria ternatea extract in cotton knitted fabric has been reported as excellent, even after six wash cycles (Dr. N. G. P., 2024). The fabric showed no discoloration within a pH range of 4–6 and no brown precipitate formation at any temperature. Acidic solutions demonstrated higher storage stability than alkaline conditions. Red extracts retained 70–80% of their color after 60 days at 27 °C and 37 °C, while red, violet, and blue extracts remained stable for at least one year at 7 °C. These findings highlight the potential applications of Clitoria ternatea extract in food, cosmetic, and pharmaceutical industries.

Anthocyanins found in butterfly pea flower extract are sensitive to high temperatures (Chusak, 2018; Mukherjee, 2008). Storage at elevated temperatures may increase chalcone formation, leading to color fading. Nevertheless, butterfly pea flower extract exhibits significantly higher color density than other natural colorants due to its high pigment concentration, contributing to its stability during storage and thermal processing.

B. *Quality of Developed Watercolor Samples*

The quality of the developed watercolor in terms of granulation, staining, transparency, and pigment number was evaluated by 30 experts using an evaluation instrument.

Table 4 shows the quality of the developed alternative watercolor paint across the three colors in terms of granulation.

Table 4 shows that the red color (beetroot), all three treatments were rated as "semi-granulating" due to the presence of small particles of beetroot powder. This occurs because the beetroot powder does not completely dissolve in the binder. As a result, the developed watercolor samples exhibit a slightly rough texture when applied to paper. This finding indicates that the percentage of beetroot powder did not significantly affect the texture of the samples. For the yellow color (turmeric), two treatments, YT25 and YT50, were rated as "non-granulating." These treatments contained a lower amount of powdered pigment and a higher amount of binder, which allowed the pigment to disperse more evenly. In contrast, YT75 was rated as "semi-granulating" due to its higher pigment content (75%) and lower binder proportion (25%). Overall, the percentage of turmeric powder influenced the texture of the samples. For the blue color (butterfly pea), all three treatments were rated as "non-granulating." This is attributed to the fine particles of butterfly pea powder, which dissolved completely in the binder. Consequently, the different treatment ratios did not affect the texture of the watercolor samples.

In summary, red watercolor samples were generally rated as "semi-granulating," while the yellow and blue samples were rated as "non-granulating." This means that the particle quality and solubility of each plant pigment affect the granulation of developed watercolors.

Meanwhile, previous studies show that beet juice is readily soluble in water and produces an intense color. In solution, the hue is somewhat pH-dependent. At pH 4 to 5, it is a bright bluish-red and probably the closest match to FD&C Red No.4. Beetroot juice powder and concentrated beetroot juice are entirely water-soluble, dried powdered beetroot contains small particles of beetroot and so are insoluble in water. While beetroot juice powder and concentrated beetroot juice are entirely water-soluble, dried beetroot powder may still contain small insoluble particles depending on the grinding process. This suggests that beetroot powder is generally water-soluble, but finer grinding is necessary to achieve complete dissolution.

Turmeric powder, on the other hand, is not readily soluble in water. While turmeric contains several soluble aromatic compounds, it also consists of proteins and cellulose that are highly insoluble. Studies have shown that heating turmeric in water can significantly improve its solubility, indicating that additional treatment is required to enhance its dispersion. Butterfly pea-extracted powder is spray-dried blue-purple powder produced by extracting the dried flowers with hot water and dextrin, making it 100% water soluble. In the process of serving powdered drinks, water is needed as a solvent so that it can be consumed. Therefore, powder drinks are closely related

Table 4
Mean score on the granulation rating of the developed watercolor

Granulation				
Red Color (Beetroots)				
Treatments	**Mean**	**Std. Deviation**	**Interpretation**	**Verbal Description**
RT25	3.13	0.90	Semi-granulating	Smoothness of 51% to 75%
RT50	2.97	0.81	Semi-granulating	Smoothness of 51% to 75%
RT75	3.00	0.87	Semi-granulating	Smoothness of 51% to 75%
Yellow Color (Turmeric)				
YT25	3.77	0.50	Non-granulating	Smoothness of 76% to 100%
YT50	3.43	0.57	Non-granulating	Smoothness of 76% to 100%
YT75	3.13	0.82	Semi-granulating	Smoothness of 51% to 75%
Blue Color (Blue Ternate)				
BT25	3.63	0.67	Non-granulating	Smoothness of 76% to 100%
BT50	3.50	0.68	Non-granulating	Smoothness of 76% to 100%
BT75	3.57	0.77	Non-granulating	Smoothness of 76% to 100%

to water. The increase in water content in food will form bonds that cause clumps to form and result in a longer time breaking bonds between particles (Permata & Sayuti, 2016). This study means that the beetroot powder is water soluble. Moreover, after testing the granulation of the developed watercolor, staining was also rated.

Table 5 presents the quality of the developed watercolor paints in terms of staining.

Table 8 shows that for the red color (beetroot), the treatments were rated as either "highly staining" or "staining." This indicates that the treatments applied during the development of the watercolor samples affected their staining quality. Specifically, RT50 obtained a "highly staining" rating, while RT25 and RT75 were rated as "staining." This may be attributed to the balanced proportion of binder and pigment in RT50. In contrast, RT25 contained a lower amount of pigment and a higher amount of binder, while RT75 contained a higher amount of pigment but a lower amount of binder. Based on the researchers' observations, the binder, particularly glycerin, acts as a preservative and enhances the staining quality of the pigment. Consequently, the 50% treatment was rated as "highly staining" due to the optimal balance between binder and pigment. Overall, all three red treatments exhibited staining properties.

For the yellow color (turmeric), all three treatments were rated as "highly staining." This indicates that the treatments did not significantly affect the staining quality of the watercolor samples, likely due to the strong pigmentation of turmeric extract.

Similarly, for the blue color (butterfly pea), all three treatments were rated as "highly staining," suggesting that the different pigment-to-binder ratios did not influence the staining quality of the samples.

In summary, the general ratings across the three colors ranged from "staining" to "highly staining." Previous studies identify beetroot pigment as an intense natural colorant ranging from red to purple and as a major commercial source of natural red dye used in the food, pharmaceutical, and cosmetic industries (Nature Shelf, 2022). This supports the observed staining capacity of beetroot-based watercolor samples.

Turmeric derives its bright yellow color from curcumin, which has been widely used as a natural coloring agent in the food industry (Campbell, 2022). Studies have shown that turmeric exhibits staining properties comparable to eosin, suggesting its potential use as a natural histological stain (Department of Allied Health Sciences, 2018). These findings support the highly staining quality observed in the turmeric-based watercolor samples.

The butterfly pea (Clitoria ternatea L.) contains anthocyanin pigments responsible for its blue coloration (Suebkhampet & Sotthibandhu, 2011). These pigments are increasingly used as natural colorants due to their stability and ease of application (Chu, 2016; Siti Azima, 2017). The use of butterfly pea extracts in this study resulted in blue watercolor samples with highly staining properties.

Following the evaluation of staining, the transparency of the watercolor samples was also assessed. Table 6 presents the quality of the developed alternative watercolor paints in terms

Table 5
Mean score on the staining rating of the developed watercolor

Staining				
Red Color (Beetroots)				
Treatments	**Mean**	**Std. Deviation**	**Interpretation**	**Verbal Description**
RT25	3.20	0.81	Staining	Staining possesses 51% to 75% pigmentation
RT50	3.63	0.56	Highly-staining	Highly-staining possesses 76% to 100% pigmentation
RT75	3.17	0.79	Staining	Staining possesses 51% to 75% pigmentation
Yellow Color (Turmeric)				
YT25	3.70	0.53	Highly-staining	Highly-staining possesses 76% to 100% pigmentation
YT50	3.53	0.68	Highly-staining	Highly-staining possesses 76% to 100% pigmentation
YT75	3.73	0.45	Highly-staining	Highly-staining possesses 76% to 100% pigmentation
Blue Color (Blue Ternate)				
BT25	3.60	0.56	Highly-staining-	Highly-staining possesses 76% to 100% pigmentation
BT50	3.73	0.52	Highly-staining-	Highly-staining possesses 76% to 100% pigmentation
BT75	3.73	0.52	Highly-staining-	Highly-staining possesses 76% to 100% pigmentation

Legend: Highly-staining (3.25-4.00), Staining (2.50-3.24), Semi-staining (1.75-2.49), Non-staining (1.00-1.74)

Table 6
Mean score on the transparency rating of the developed watercolor

Transparency				
Red Color (Beetroots)				
Treatments	**Mean**	**Std. Deviation**	**Interpretation**	**Verbal Description**
RT25	3.27	0.83	Opaque	Pigmentation of 76% to 100%
RT50	3.37	0.56	Opaque	Pigmentation of 76% to 100%
RT75	3.33	0.76	Opaque	Pigmentation of 76% to 100%
Yellow Color (Turmeric)				
YT25	3.27	0.83	Opaque	Pigmentation of 76% to 100%
YT50	3.37	0.56	Opaque	Pigmentation of 76% to 100%
YT75	3.33	0.76	Opaque	Pigmentation of 76% to 100%
Blue Color (Blue Ternate)				
BT25	3.40	0.67	Opaque	Pigmentation of 76% to 100%
BT50	3.50	0.68	Opaque	Pigmentation of 76% to 100%
BT75	3.60	0.56	Opaque	Pigmentation of 76% to 100%

Legend: Opaque (3.25-4.00), Semi-opaque (2.50-3.24), Semi-transparent (1.75-2.49), Transparent (1.00-1.74)

Table 7
Mean score on the pigment number rating of the developed watercolor

Treatments	Mean	Std. Deviation	Interpretation	Verbal Description
Pigment Number				
Red Color (Beetroots)				
RT25	3.10	0.80	Triple Pigments	Triple Pigments produced three (3) colors
RT50	3.50	0.57	Multiple Pigments	Multiple Pigment produced more than three colors
RT75	3.23	0.77	Triple Pigments	Triple Pigments produced three (3) colors
Yellow Color (Turmeric)				
YT25	3.57	0.63	Multiple Pigments	Multiple Pigment produced more than three colors
YT50	3.57	0.68	Multiple Pigments	Multiple Pigment produced more than three colors
YT75	3.53	0.73	Multiple Pigments	Multiple Pigment produced more than three colors
Blue Color (Blue Ternate)				
BT25	3.50	0.68	Multiple Pigments	Multiple Pigment produced more than three colors
BT50	3.63	0.56	Multiple Pigments	Multiple Pigment produced more than three colors
BT75	3.77	0.63	Multiple Pigments	Multiple Pigment produced more than three colors

of transparency.

Table 6 shows that the red color (beetroot), yellow color (turmeric), and blue color (butterfly pea) were all rated as "opaque" across all treatment samples. Opaque indicates that each treatment sample produced thick and dense shades of color. These results signify that the three treatments applied during the development process did not affect the transparency quality of the watercolor samples.

In summary, all three colors and their respective treatments were consistently rated as "opaque." Previous studies indicate that transparency and opacity in watercolor depend on the proportion of pigment and binder. A higher pigment concentration in butterfly pea, for instance, produces more opaque characteristics, while a lower pigment concentration results in greater transparency (Sophie Spray, 2022). Watercolor transparency is also directly influenced by pigment dilution. Even typically opaque pigments can appear transparent when sufficiently diluted with water, whereas transparent pigments can become opaque when applied in thicker layers (Lovett, 2022). These findings support the results of the present study, where consistent pigment-to-binder ratios resulted in uniformly opaque watercolor samples.

Table 7 shows the quality of the developed watercolor in terms of pigment number.

It is shown in Table 7 that the Red color (beetroots), across the three treatments, was rated as "Multiple Pigments." This indicates that the treatment was applied but did not affect the number of pigments produced in each color sample. For the Yellow color (turmeric), all three treatments were also rated as "Multiple Pigments," meaning that the treatment did not alter the number of pigments produced in each sample. Similarly, for the Blue color (blue ternate), the three treatments were rated as "Multiple Pigments," which again indicates that the treatment did not affect pigment production in the samples.

In summary, the general rating across all three colors was "Multiple Pigments." Red beetroots produced deep red, dark red, and bright red colors (Karen Cox, 2024). According to the Science Institute, the flesh of the turmeric rhizome is orange-brown, yellow, or reddish-yellow. Ground-dried turmeric is soft, fine, and bright yellow-orange in color, with compounds called curcuminoids responsible for its vibrant hue. Blue Ternate (Clitoria ternatea) produced multiple colors, including vivid deep blue, bright blue, dark purple, and deep midnight cobalt (Goldberg, 2016). A study by CSSR (2010) found that the color of Clitoria ternatea anthocyanin extract (CTAE) varies depending on pH. The anthocyanin pigment displayed colors ranging from intense red, violet, and blue to blue-green, green, and yellow within a pH range of 0.05 to 12.0. This variation is caused by structural changes in the anthocyanin in response to different pH levels. These findings suggest that plants can naturally produce a wide range of color shades.

C. Differences in the Evaluated Quality of Developed Watercolor Samples

The significant differences of the developed watercolor samples in terms of granulation, staining, transparency, and pigment number in comparison with control samples were identified using inferential statistics such as parametric test – F-test or ANOVA (Analysis of Variance).

Table 8 shows the significant difference between the developed watercolor samples and control samples in terms of red color.

It is shown in Table 8 that the ANOVA of the red-developed product and control samples revealed that three out of four parameters, or 75%, granulating, staining, and pigment number, were rated as "significant," while one out of four, or 25%, which is transparency, was rated as "not significant."

Granulating was rated as "significant" because the beetroot powder did not fully dissolve in the binder, resulting in a granular texture. In contrast, the control samples exhibited a fine, non-granulating texture. Staining was rated as "significant" because the developed watercolor exhibited lower staining quality than the control samples due to the slight pigmentation of beetroot. Transparency was rated "not significant," indicating that there is no difference between the developed watercolor and the control samples in transparency, and that the developed watercolor achieves the same quality as the controls. The pigment number was rated as "significant" because the developed watercolor produced more pigments than the control samples. Overall, the results in this table indicate that the red watercolor shows significant differences compared to the control samples.

Beetroot (Beta vulgaris) is an excellent source of natural red colorant. In this study, red beetroot dye was prepared as a powder and subsequently used to color candies. According to reported studies, betalains are heat-sensitive pigments that lose stability at higher temperatures (Reshmi, 2012; Nisa, 2015). Temperature is the most important factor affecting betalain stability during food processing and storage (Herbach, 2006).

Table 8
ANOVA of developed watercolor samples and control samples in terms of red color

Red Color (Beetroots)

Granulating

Sum of Squares	df	Mean Square	F	Sig.	Interpretation
34.107	4	8.527			
64.433	145	.444	19.188	.000	Significant
98.540	149				

Tukey HSD

Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Upper Bound	
Granulating	Control1	Control2	0.00000	.17212	1.000	-.4755	.4755
		25%	.86667*	.17212	.000	.3912	1.3421
		50%	1.03333*	.17212	.000	.5579	1.5088
		75%	1.00000*	.17212	.000	.5245	1.4755
	Control2	Control1	0.00000	.17212	1.000	-.4755	.4755
		25%	.86667*	.17212	.000	.3912	1.3421
		50%	1.03333*	.17212	.000	.5579	1.5088
		75%	1.00000*	.17212	.000	.5245	1.4755
	25%	Control1	-.86667*	.17212	.000	-1.3421	-.3912
		Control2	-.86667*	.17212	.000	-1.3421	-.3912
		50%	.16667	.17212	.869	-.3088	.6421
		75%	.13333	.17212	.938	-.3421	.6088
	50%	Control1	-1.03333*	.17212	.000	-1.5088	-.5579
		Control2	-1.03333*	.17212	.000	-1.5088	-.5579
		25%	-.16667	.17212	.869	-.6421	.3088
		75%	-.03333	.17212	1.000	-.5088	.4421
	75%	Control1	-1.00000*	.17212	.000	-1.4755	-.5245
		Control2	-1.00000*	.17212	.000	-1.4755	-.5245
		25%	-.13333	.17212	.938	-.6088	.3421
		50%	.03333	.17212	1.000	-.4421	.5088

Staining

	Sum of Squares	df	Mean Square	F	Sig.	Interpretation
Between Groups	7.773	4	1.943			
Within Groups	59.300	145	.409	4.752	.001	Significant
Total	67.073	149				

Tukey HSD

Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Upper Bound	
Staining	Control1	Control2	-.23333	.16512	.620	-.6895	.2228
		25%	.30000	.16512	.368	-.1561	.7561
		50%	-.13333	.16512	.928	-.5895	.3228
		75%	.33333	.16512	.262	-.1228	.7895
	Control2	Control1	.23333	.16512	.620	-.2228	.6895
		25%	.53333*	.16512	.013	.0772	.9895
		50%	.10000	.16512	.974	-.3561	.5561
		75%	.56667*	.16512	.007	.1105	1.0228
	25%	Control1	-.30000	.16512	.368	-.7561	.1561
		Control2	-.53333*	.16512	.013	-.9895	-.0772
		50%	-.43333	.16512	.071	-.8895	.0228
		75%	.03333	.16512	1.000	-.4228	.4895
	50%	Control1	.13333	.16512	.928	-.3228	.5895
		Control2	-.10000	.16512	.974	-.5561	.3561
		25%	.43333	.16512	.071	-.0228	.8895
		75%	.46667*	.16512	.042	.0105	.9228
	75%	Control1	-.33333	.16512	.262	-.7895	.1228
		Control2	-.56667*	.16512	.007	-1.0228	-.1105
		25%	-.03333	.16512	1.000	-.4895	.4228
		50%	-.46667*	.16512	.042	-.9228	-.0105

Transparency

	Sum of Squares	df	Mean Square	F	Sig.	Interpretation
Between Groups	.307	4	.077			
Within Groups	65.667	145	.453	.169	.954	Not Significant
Total	65.973	149				

Pigment Number

	Sum of Squares	df	Mean Square	F	Sig.	Interpretation
Between Groups	24.533	4	6.133			
Within Groups	60.300	145	.416	14.748	.000	Significant
Total	84.833	149				

Tukey HSD							
Dependent Variable			**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**95% Confidence Interval Upper Bound**	
Pigment Number	Control1	Control2	-.13333	.16651	.930	-.5933	.3266
		25%	-.66667*	.16651	.001	-1.1266	-.2067
		50%	-1.06667*	.16651	.000	-1.5266	-.6067
		75%	-.80000*	.16651	.000	-1.2600	-.3400
	Control2	Control1	.13333	.16651	.930	-.3266	.5933
		25%	-.53333*	.16651	.014	-.9933	-.0734
		50%	-.93333*	.16651	.000	-1.3933	-.4734
		75%	-.66667*	.16651	.001	-1.1266	-.2067
	25%	Control1	.66667*	.16651	.001	.2067	1.1266
		Control2	.53333*	.16651	.014	.0734	.9933
		50%	-.40000	.16651	.121	-.8600	.0600
		75%	-.13333	.16651	.930	-.5933	.3266
	50%	Control1	1.06667*	.16651	.000	.6067	1.5266
		Control2	.93333*	.16651	.000	.4734	1.3933
		25%	.40000	.16651	.121	-.0600	.8600
		75%	.26667	.16651	.499	-.1933	.7266
	75%	Control1	.80000*	.16651	.000	.3400	1.2600
		Control2	.66667*	.16651	.001	.2067	1.1266
		25%	.13333	.16651	.930	-.3266	.5933
		50%	-.26667	.16651	.499	-.7266	.1933

Table 9

ANOVA of watercolor samples and control samples in terms of yellow color

Yellow (Turmeric)

Granulation

	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**	**Interpretation**
Between Groups	17.133	4	4.283			
Within Groups	36.200	145	.250	17.157	.000	Significant
Total	53.333	149				

Tukey HSD							
Dependent Variable			**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**95% Confidence Interval Upper Bound**	
Granulating	Control1	Control2	0.00000	.12901	1.000	-.3564	.3564
		25%	.23333	.12901	.373	-.1230	.5897
		50%	.56667*	.12901	.000	.2103	.9230
		75%	.86667*	.12901	.000	.5103	1.2230
	Control2	Control1	0.00000	.12901	1.000	-.3564	.3564
		25%	.23333	.12901	.373	-.1230	.5897
		50%	.56667*	.12901	.000	.2103	.9230
		75%	.86667*	.12901	.000	.5103	1.2230
	25%	Control1	-.23333	.12901	.373	-.5897	.1230
		Control2	-.23333	.12901	.373	-.5897	.1230
		50%	.33333	.12901	.079	-.0230	.6897
		75%	.63333*	.12901	.000	.2770	.9897
	50%	Control1	-.56667*	.12901	.000	-.9230	-.2103
		Control2	-.56667*	.12901	.000	-.9230	-.2103
		25%	-.33333	.12901	.079	-.6897	.0230
		75%	.30000	.12901	.143	-.0564	.6564
	75%	Control1	-.86667*	.12901	.000	-1.2230	-.5103
		Control2	-.86667*	.12901	.000	-1.2230	-.5103
		25%	-.63333*	.12901	.000	-.9897	-.2770
		50%	-.30000	.12901	.143	-.6564	.0564

Staining

	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**	**Interpretation**
Between Groups	.760	4	.190			
Within Groups	42.233	145	.291	.652	.626	Not Significant
Total	42.993	149				

Transparency

	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**	**Interpretation**
Between Groups	3.373	4	.843			
Within Groups	59.167	145	.408	2.067	.088	Not Significant
Total	62.540	149				

Pigment Number

	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**	**Interpretation**
Between Groups	51.907	4	12.977			
Within Groups	53.133	145	.366	35.413	.000	Significant
Total	105.040	149				

Tukey HSD							
Dependent Variable			**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**95% Confidence Interval Upper Bound**	
Pigment Number	Control1	Control2	.20000	.15630	.704	-.2318	.6318
		25%	-1.10000*	.15630	.000	-1.5318	-.6682
		50%	-1.00000*	.15630	.000	-1.4318	-.5682
		75%	-1.16667*	.15630	.000	-1.5984	-.7349
	Control2	Control1	-.20000	.15630	.704	-.6318	.2318
		25%	-1.30000*	.15630	.000	-1.7318	-.8682
		50%	-1.20000*	.15630	.000	-1.6318	-.7682
		75%	-1.36667*	.15630	.000	-1.7984	-.9349
	25%	Control1	1.10000*	.15630	.000	.6682	1.5318
		Control2	1.30000*	.15630	.000	.8682	1.7318
		50%	.10000	.15630	.968	-.3318	.5318
		75%	-.06667	.15630	.993	-.4984	.3651
	50%	Control1	1.00000*	.15630	.000	.5682	1.4318
		Control2	1.20000*	.15630	.000	.7682	1.6318
		25%	-.10000	.15630	.968	-.5318	.3318
		75%	-.16667	.15630	.823	-.5984	.2651
	75%	Control1	1.16667*	.15630	.000	.7349	1.5984
		Control2	1.36667*	.15630	.000	.9349	1.7984
		25%	.06667	.15630	.993	-.3651	.4984
		50%	.16667	.15630	.823	-.2651	.5984

Table 10
ANOVA of watercolor samples with control samples in terms of blue color

Blue Color (Blue Ternate)

Granulation

	Sum of Squares	df	Mean Square	F	Sig.	Interpretation
Between Groups	7.027	4	1.757			
Within Groups	43.833	145	.302	5.811	.000	Significant
Total	50.860	149				

Tukey HSD

Dependent Variable			**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**95% Confidence Interval Upper Bound**	
Granulating	Control1	Control2	0.00000	.14196	1.000	-.3922	.3922
		25%	.36667	.14196	.079	-.0255	.7588
		50%	.50000*	.14196	.005	.1078	.8922
		75%	.43333*	.14196	.02 2	.0412	.8255
	Control2	Control1	0.00000	.14196	1.000	-.3922	.3922
		25%	.36667	.14196	.079	-.0255	.7588
		50%	.50000*	.14196	.005	.1078	.8922
		75%	.43333*	.14196	.022	.0412	.8255
	25%	Control1	-.36667	.14196	.079	-.7588	.0255
		Control2	-.36667	.14196	.079	-.7588	.0255
		50%	.13333	.14196	.881	-.2588	.5255
		75%	.06667	.14196	.990	-.3255	.4588
	50%	Control1	-.50000*	.14196	.005	-.8922	-.1078
		Control2	-.50000*	.14196	.005	-.8922	-.1078
		25%	-.13333	.14196	.881	-.5255	.2588
		75%	-.06667	.14196	.990	-.4588	.3255
	75%	Control1	-.43333*	.14196	.022	-.8255	-.0412
		Control2	-.43333*	.14196	.022	-.8255	-.0412
		25%	-.06667	.14196	.990	-.4588	.3255
		50%	.06667	.14196	.990	-.3255	.4588

Staining

	Sum of Squares	df	Mean Square	F	Sig.	Interpretation
Between Groups	.627	4	.157			
Within Groups	39.267	145	.271	.579	.679	Not Significant
Total	39.893	149				

Transparency

	Sum of Squares	df	Mean Square	F	Sig.	Interpretation
Between Groups	1.107	4	.277			
Within Groups	56.067	145	.387	.716	.583	Not Significant
Total	57.173	149				

Pigment Number

	Sum of Squares	df	Mean Square	F	Sig.	Interpretation
Between Groups	58.893	4	14.723			
Within Groups	47.700	145	.329	44.756	.000	Significant
Total	106.593	149				

Tukey HSD							
Dependent Variable			**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**95% Confidence Interval Upper Bound**	
Pigment Number	Control1	Control2	-.06667	.14809	.991	-.4758	.3424
		25%	-1.16667*	.14809	.000	-1.5758	-.7576
		50%	-1.30000*	.14809	.000	-1.7091	-.8909
		75%	-1.43333*	.14809	.000	-1.8424	-1.0242
	Control2	Control1	.06667	.14809	.991	-.3424	.4758
		25%	-1.10000*	.14809	.000	-1.5091	-.6909
		50%	-1.23333*	.14809	.000	-1.6424	-.8242
		75%	-1.36667*	.14809	.000	-1.7758	-.9576
	25%	Control1	1.16667*	.14809	.000	.7576	1.5758
		Control2	1.10000*	.14809	.000	.6909	1.5091
		50%	-.13333	.14809	.896	-.5424	.2758
		75%	-.26667	.14809	.377	-.6758	.1424
	50%	Control1	1.30000*	.14809	.000	.8909	1.7091
		Control2	1.23333*	.14809	.000	.8242	1.6424
		25%	.13333	.14809	.896	-.2758	.5424
		75%	-.13333	.14809	.896	-.5424	.2758
	75%	Control1	1.43333*	.14809	.000	1.0242	1.8424
		Control2	1.36667*	.14809	.000	.9576	1.7758
		25%	.26667	.14809	.377	-.1424	.6758
		50%	.13333	.14809	.896	-.2758	.5424

The thermal stability of betalains, according to Herbach (2016), depends on heating time, temperature, and other factors such as light exposure and pigment structure. Another study reported that betalain degradation increases progressively with rising temperature and prolonged storage time (Halwani, 2018). Similarly, a significant reduction in betalain content was observed at 40°C, room temperature, and refrigeration temperatures (Mohammed, 2021).

After identifying significant differences between the red-developed watercolor and control samples, the yellow color was also evaluated. Table 9 shows the significant differences between the developed alternative watercolor and control samples in terms of yellow color.

It is shown in Table 9 that the ANOVA of the yellow-developed product and control samples revealed that two out of four variables, or 50%—granulating and pigment number—were rated as "significant," while the other two variables, staining and transparency, were rated as "not significant."

Granulating was rated "significant" because the turmeric did not fully dissolve in the binder, resulting in a slightly granular texture. In contrast, the control samples exhibited a fine, non-granulating texture. Staining was rated as "not significant," indicating that the developed watercolor has the same staining quality as the control samples, due to turmeric's bright yellow color. Transparency was also rated "not significant," indicating no difference between the developed watercolor and the control samples, and that the developed watercolor achieves the same quality as the controls. The pigment number was rated as "significant" because the developed watercolor produced more pigment than the control samples.

Although turmeric has not yet been officially recognized by the Biological Stain Commission (2019), research has indicated its potential as a substitute for synthetic dyes. The primary component of turmeric, curcumin, possesses distinctive properties. Natural dyes such as turmeric offer a safer alternative, as they generally pose no health risks. Turmeric, a rhizomatous herb in the Zingiberaceae family, is commonly used as a substitute for Eosin, a synthetic dye. Curcumin, the principal coloring pigment in turmeric, imparts a yellow hue to the cytoplasmic components of cells. The ability of a dye to stain specific tissue structures is influenced by various factors, including the dye's acidity: acidic structures are typically stained by basic dyes, while basic structures are typically stained by acidic dyes. Curcuma longa can also be considered an alternative cytoplasmic stain due to its effectiveness in staining cytoplasm and its environmentally friendly nature. Recent studies have explored the use of Curcuma longa in staining tissue sections. This study is a preliminary investigation utilizing Curcuma longa as a cytological stain in cytosmears. The findings suggest that turmeric is a promising yellow pigment and may serve as a viable replacement for synthetic dyes.

Furthermore, after identifying significant differences between the yellow-developed watercolor and control samples, the blue color was also evaluated. Table 10 shows the significant differences between the developed alternative watercolor and control samples in terms of blue color.

Table 10 shows that the ANOVA of the blue-developed product and control samples revealed that two of the four variables, or 50%, granulating and pigment number, were rated as "significant." In comparison, the remaining two variables, staining and transparency, were rated as "not significant."

Granulating was rated as "significant" because the blue ternate did not completely dissolve in the binder, resulting in a slightly granulating texture. In contrast, the control samples exhibited a fine, non-granulating texture. Staining was rated as "not significant," indicating that the developed watercolor has the same staining quality as the control samples. Transparency was also rated as "not significant," indicating that there is no difference between the developed watercolor and the control samples in transparency, and that the developed watercolor attains the same quality as the controls. The pigment number was rated as "significant" because the developed watercolor produced more pigment than the control samples.

Butterfly pea flower extracts can be used as a natural blue colorant, easy to apply, and with a longer shelf life than other plant-based colorants (Siti Azima, 2017). Blue pea flower anthocyanins can be incorporated into acidic and neutral foods as a blue food colorant. The addition of these anthocyanins can enhance functional properties such as antioxidant and antimicrobial activities. Furthermore, blue pea flower anthocyanins have been utilized in intelligent packaging applications. Comparisons between blue pea flower anthocyanins and other natural blue coloring agents used in the food industry, such as spirulina (phycocyanin) and genipin-derived pigments, have also been discussed. Anthocyanins extracted from blue pea flowers show strong potential as natural blue food coloring agents (Vidana Gamage, 2021).

Clitoria ternatea, an underutilized herbaceous flower in Sri Lanka, is known for its characteristic intense blue coloration, which is due to the presence of anthocyanins, which can be used as a natural coloring agent (Vankar and Srivastava, 2010). These studies highlight the potential of blue ternate as a valuable source of natural blue color.

4. Conclusion

Based on the observation, results, and findings of this study, the following are hereby concluded:

1. The three treatments and two controls in red have a cool shade of red. For the yellow color, the three treatments show a cool shade, while the two control samples show a warm shade. For the blue color, three treatments and two controls have a cool shade of blue. In terms of lightfastness, the RT25 and RT75 were rated as "semi-fugitive" in red, while the RT50 was rated as "non-fugitive" in red. In yellow color, the YT25 and YT57 were rated as "impermanent" while the YT50 was rated as "non-fugitive". In blue, the BT25 and BT75 were rated as "semi-fugitive," while the BT50 was rated as "non-fugitive."
2. In terms of granulation, the three red treatments were rated as semi-granulating. The three treatments of yellow and blue colors were rated as non-granulating. In terms of staining, RT50 was rated as staining, and RT25 and RT75 were highly staining, while the three treatments with yellow and blue colors were rated as highly staining. In terms of transparency, the three treatments of red, yellow, and blue colors were rated as opaque. In terms of pigment number, the RT50 was rated as triple pigments, and RT25 and RT75 were rated as multiple pigments. In contrast, three treatments of yellow and blue colors were rated as various pigments.
3. In terms of red color, three out of four (75%) granulating, staining, and pigment numbers are rated as "significant". While 25% of transparency is rated as "not-significant". In terms of yellow color, two out of four variables, or 50%, which are granulating and pigment number, are rated as "significant". While the two variables, staining and transparency, were rated as "not significant. In terms of blue color, two out of four variables, or 50%, which are granulating and pigment number, were rated as "significant". While the two variables, staining and transparency, were rated as "not-significant".

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