Formulation of Eco-Crayons Using Organic Pigments and Natural Waxes (Soy Wax, Palm Wax, and Beeswax)

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***Abstract*: This study, titled Formulation of Eco-Crayons Using Organic Pigments from Botanical Flowers and Natural Waxes such as Soy Wax, Palm Wax, and Beeswax, aimed to develop safe, sustainable, and non-toxic alternatives to conventional petroleum-based crayons. Using an experimental design, the research evaluated the durability and color vibrancy of eco-crayons made with natural pigments from rose (red), butterfly pea (blue), and sunflower (yellow), combined with soy wax, palm wax, and beeswax. Durability was assessed through a drop test, while color intensity and consistency were measured with a colorimeter. Data were analyzed using one-way ANOVA to determine significant differences among the wax formulations. Results showed that beeswax produced the most durable crayons with a smooth texture, soy wax provided the most vibrant and consistent color but was soft and easily breakable, and palm wax was smooth but exhibited weaker color release and lower durability. Statistical analysis revealed no significant differences at the 0.05 significance level. The study concludes that natural waxes and botanical pigments can produce high-quality, eco-friendly crayons suitable for young learners, emphasizing the integration of safety and sustainability in educational materials and promoting innovation in environmentally conscious art product.**

***Keywords*: Enter key words or phrases in alphabetical order, separated by commas.**

1. Introduction

A. Background of the Study

Children's art supplies are widely used in homes, schools, and early childhood education settings. Among these materials, crayons are the most frequently used tools for drawing and coloring that help enhance children's imagination, creativity, and fine motor skills (Formosa Publisher, 2023). However, because young children often handle, mouth, or accidentally ingest these materials, the safety chemical composition is critically important (National Library of Medicine, 2023). Since crayons are commonly used in early childhood, it is crucial to guarantee that they are safe, non-toxic, and eco-friendly. Traditional crayons, which are made from petroleum-based waxes and artificial colorants, may expose children to harmful chemicals. Therefore, creating a safer substitute that prioritizes both health and environmental protection is essential.

Based on the Consumer Council (2021) and Magramo (2021), growing concerns have emerged regarding the environmental impact and chemical safety of traditional crayons, which are primarily made from paraffin wax a petroleum byproduct and often contain harmful substances such as polycyclic aromatic hydrocarbons (PAHs). These petroleum-based compounds pose both health and ecological risks, highlighting the urgent need for safer and more sustainable alternatives in educational materials. Developing eco-friendly crayons not only addresses environmental and health concerns but also supports science learning and sustainability education by integrating real-world environmental issues into the curriculum, encouraging students to understand and practice eco-conscious decision-making.

In response, there is growing interest in natural, non-toxic, biodegradable alternatives. Natural waxes such beeswax, soy wax, and palm wax, and blends thereof, together with organic or botanical pigments derived from flowers and plants, are promising as safer substitutes. Beeswax, for instance, is biodegradable, hypoallergenic, and free from the chemical additives found in petroleum-based waxes (Smilogy Kids, 2024). Previous research has also shown that crayons made from natural waxes and organic additives can be produced safely without containing harmful heavy metals (Universiti Teknikal Malaysia Melaka, 2024). However, further research is still needed to optimize these eco-crayons in terms of durability and color vibrancy.

B. Statement of the Problem

This study seeks to address the increasing demand for safe, eco-friendly, and sustainable art materials for young learners by developing eco-crayons made from natural pigments, botanical flower extracts, and natural waxes.

Specifically, the problem of this study is expressed in the following questions:

1. How do soy wax, palm wax, and beeswax affect the physical properties of eco-crayons in terms of durability?
2. How does the color vibrancy of eco-crayons affect the functionality of those made from natural waxes such

as palm wax, soy wax, and beeswax and botanical pigments extracted from rose for red color, butterfly pea flower for blue color, and sunflower for yellow color?

C. *Objectives*

To evaluate the effectiveness of eco-crayons made from botanical flowers and natural waxes as a sustainable alternative to commercial crayons in terms of:

- Resistance to wear and breakage is a measure of durability; and
- When applied to paper, color quality is determined by the color vibrancy and consistency

D. *Conceptual Framework*

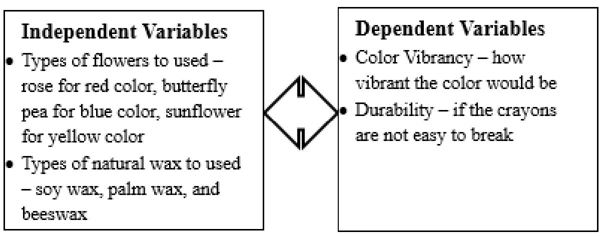

Fig. 1. The conceptual framework of the study

Figure 1.1 shows the variables of the study. It can be observed that the types of flowers such as rose for red pigment, butterfly pea for blue pigment, and sunflower for yellow pigment as well as the types of waxes, namely soy wax, palm wax, and beeswax, serve as the independent variables of the study. These variables are manipulated to determine their effects on the outcomes of the experiment. Conversely, color vibrancy and durability function as the dependent variables, as their values vary in response to changes in the independent variables. The measurements of these dependent variables depend on the concentration or amount of pigment and type of wax used in the formulation process.

E. *Hypothesis*

Null Hypothesis (H0):

- At 5% level of significance, there is no significant difference in the durability of eco-crayons made from soy wax, palm wax, and bees wax.
- At 5% level of significance, there is no significant difference in the color vibrancy of eco-crayons made from soy wax, palm wax, and beeswax.

Alternative Hypothesis (H1):

- There is a significant difference in the durability of eco-crayons made from soy wax, palm wax, and beeswax.
- There is a significant difference in the color vibrancy of eco-crayons made from soy wax, palm wax, and beeswax.

F. *Significance of the Study*

This study explores the potential for developing sustainable, non-toxic, and environmentally friendly alternatives to conventional crayons through the formulation of eco-crayons using pigments derived from botanical flowers and natural waxes such as soy wax, beeswax, and palm wax. The outcomes may offer benefits for students, parents, teachers, and the wider community. Since crayons are commonly used by early childhood and elementary students and often come into contact with the skin or, in some cases, are accidentally ingested, using crayons made from natural pigments and waxes could reduce children's exposure to harmful substances found in some commercial products.

Beyond their material advantages, the use of eco-crayons has strong educational implications. Integrating these sustainable materials into classroom activities supports curriculum goals in science, health, and environmental education, as learners can directly engage in discussions and experiments about natural resources, chemical safety, and ecological preservation. Teachers can utilize eco-crayons as instructional tools to connect environmental concepts with hands-on creative learning, fostering early awareness of sustainability and responsible consumption. Moreover, this approach aligns with the DepEd's advocacy for environmental literacy and sustainable practices, providing opportunities for interdisciplinary lessons that combine art, science, and social responsibility (Department of Education, 2019)

This study also seeks to explore the feasibility of producing biodegradable crayon alternatives that align with safety and environmental considerations. The use of eco-crayons might contribute to reducing reliance on petroleum-based ingredients and synthetic dyes typically present in traditional crayons. Sourcing botanical pigments and natural waxes locally could support ecological sustainability and open possibilities for community-driven initiatives or small-scale enterprises. By examining factors such as color vibrancy and durability, the research aims to identify which waxes are most suitable for eco-crayon production, offering insights that can guide future studies and inform the development of sustainable art materials that strengthen environmental values in education.

G. *Scope and Delimitation*

The scope and limitations of this study encompass the period from August to October 2025. The research primarily focuses on the development of eco-friendly crayons formulated using natural pigments extracted from selected botanical flowers and natural waxes, specifically soy wax, beeswax, and palm wax.

The scope of the study includes the extraction of pigments from the petals of selected botanical flowers rose (red pigment), butterfly pea (blue pigment), and sunflower (yellow pigment) which were chosen for their high pigment concentration, natural availability, and non-toxic properties. These flowers are widely accessible in local environments, making them suitable for sustainable and cost-efficient pigment extraction. The formulation process involves combining these natural pigments with soy wax, beeswax, and palm wax, chosen for their biodegradability, non-toxicity, and renewable origins. Soy wax offers smooth texture and easy blending, beeswax provides natural hardness and gloss, and palm wax contributes durability and vibrant color retention.

This study is delimited to the use of flower petals as the sole source of pigments, excluding other plant parts such as stems, leaves, and roots to ensure consistency of color extraction and avoid impurities that may alter the pigment quality. Similarly, only soy wax, beeswax, and palm wax are employed in the formulation because they represent three distinct categories of plant-based, animal-derived, and vegetable waxes, allowing for meaningful comparison across natural wax types. The study does not include synthetic additives, stabilizers, or commercial-grade color enhancers to maintain the ecological integrity of the formulations. Furthermore, the research is confined to small-scale laboratory formulation and testing and does not extend to industrial-scale production or long-term storage assessments. Evaluation is limited to the crayons' physical and functional characteristics, excluding factors such as market feasibility or user preference testing.

H. *Definition of Terms*

This study encompasses the following terms:

1) *Conceptual Terms:*

- *Anthocyanins* - any various soluble pigments producing blue to red coloring in flowers
- *Botanical* - substance obtained or derived from a plant
- *Carotenoids* - a class of natural pigments responsible for the vibrant
- *Derived* - being, possessing, or marked by a character (such as the large brain in humans) not present in the ancestral form
- *Immersive* - providing, involving, or characterized by deep absorption or immersion in something (such as an activity or a real or artificial environment)
- *Interrogative* - an expression often used to test knowledge
- *Perception* - a result of perceiving: observation
- *Scalability* - scalability measures a system's ability to handle an increasing amount of work
- *Tactile* - relating to, or being the sense of touch
- *Vividness* - of a color: very strong: very high in chroma

2) *Operational Terms:*

- *Anthocyanins* - In the researcher's study, anthocyanins defined a natural, water-soluble pigment, which created red, purple, and blue hues, and are abundant in flowers like roses and lavender. Eco-crayons can utilize these pigments extracting them from floral sources to provide vibrant color
- *Botanical* - In the context of the study, botanical is a pigments derived from flowers are natural colorants extracted from various floral sources
- *Carotenoids* - In the context of the study, carotenoids defined a class of natural pigments responsible for the vibrant
- *Derived* - In the researcher's study, derived defined the pigments used in natural crayons may be obtained from fruits and vegetables, therefore the color is taken from the natural dyes present in these foods
- *Immersive* - In the context of the study, immersive defined the number of senses engaged in an activity increases as an additional feature or element is introduced, such as touch and sights
- *Interrogative* - In the researcher's study, interrogative defined to the questioning or investigate approach used to explore different formulations, test hypothesis, and gather data on the properties of the eco-crayons
- *Perception* - In the researcher's study, perception defined observing the formulation of making eco-crayons
- *Scalability* - In the context of the study, scalability is the ability to increase the production volume of the eco-crayons easily and efficiently, depending on demand while maintaining quality and cost-effectiveness
- *Tactile* - In the context of the study, tactile defined to create a tangible product which is crayons, "tangible" refers to something that has a physical shape that can be seen, felt, and utilized
- *Vividness* - In the researcher's study, vividness defined the number of senses engaged in an activity increase as an additional feature or element is introduced, such as touch and sights.

2. Guidelines

A. *Research Design*

The study employs an experimental research design to evaluate the formulation and performance of eco-crayons made from botanical flower pigments and natural waxes, specifically soy wax, palm wax, and beeswax. According to Arbolado et al. (2024), the experimental research design is appropriate when the goal is to determine cause-and-effect relationships through the systematic manipulation and control of variables. This design enables the researchers to observe how different natural wax types interact with pigments extracted from selected botanical flowers such as rose (red), butterfly pea (blue), and sunflower (yellow), as suggested by Ryu (2024).

To ensure accuracy and consistency, several variables will be controlled throughout the experiment. These include the temperature during wax melting and blending, the wax-to-pigment ratio across all samples, molding time, drying duration, and application pressure during testing. By maintaining these parameters constant, the study ensures that observed differences in crayon performance specifically in color vibrancy and durability can be attributed primarily to the type of natural wax used rather than to external factors.

Furthermore, the data obtained from color vibrancy (via colorimeter testing) and durability (via drop testing) will be analyzed using a One-Way Analysis of Variance (ANOVA).

This statistical test is suitable because it allows comparison of the mean differences among three independent groups of the crayons formulated with soy wax, palm wax, and beeswax to determine whether the type of wax has a statistically significant effect on the measured properties. The use of ANOVA ensures objective, data-driven interpretation of results and validates whether the observed variations are due to the experimental treatments rather than random chance.

B. Procedure and Materials

1) Phase 1 – Pigment Extraction

Prepare the materials needed for pigment extraction. Botanical flowers (roses for red, butterfly pea flower for blue, and sunflower for yellow), 3 containers, hot water, cream of tartar, organic kaolin clay, coffee filter paper, sieve.

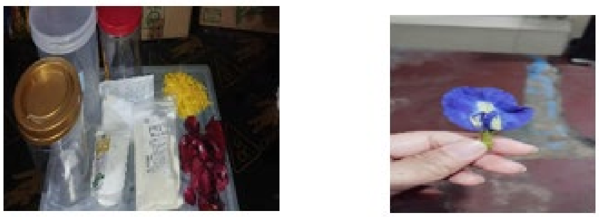

Fig. 2. Prepare materials needed

Soak the petals in 1.5 liters of hot water for about 12 to 24 hours. After soaking the petals, remove the flowers and squeeze the remaining juice from the petals.

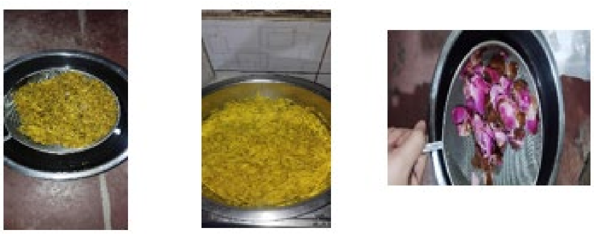

Fig. 3. Soak petals in hot water

In two different containers, put 500 ml of the flower soaked water in each container. Leave 500 ml in the first container. In the second container, put 4 tablespoons of organic kaolin clay and stir. Kaolin clay serves as the alternative precipitating agent to separate the pigment to the water.

Fig. 4. Add kaolin clay

In the third container, put 3 tablespoons of cream of tartar and stir. Cream of tartar serves as the alternative mordant to bind and fix the color. Gradually add the mixture with organic kaolin clay and mixture with cream of tartar to the first container gradually while mixing it.

Fig. 5. Add cream of tartar

After the mixture is combined, leave it for at least 24 hours to separate the pigment from the water.

Fig. 6. Leave it to separate pigment

When the mixture separates, filter the mixture using the coffee filter and leave it for about 24 hours to fully drain.

Fig. 7. Filter the mixture

When the pigment is drained, remove it from the coffee filter and transfer it to the pan. Let it dry in the oven for about 60 minutes with the temperature of 100°C. Add more time if it is not completely dry.

Fig. 8. Dry the pigment

If the pigment is dried in the oven, transfer it to the mortar and pestle to grind into fine powder. Make sure it is completely dry. To know if it is ready for grinding, break a piece on your finger. If the texture is brittle and dry, it is now ready to grind into fine powder.

Fig. 9. Grind the pigment

After grinding, the powder should be fine. Sift the powder to know if there's still clumped powder. If so, grind it again. When the power is fine, it is ready to use for crayon making.

Fig. 10. Powdered pigment is done

2) Phase 2 – Crayon Making

Prepare the materials needed. These include improvised double boiler, soy wax, palm wax, beeswax, crayon molder, powdered pigments, citrus scented oil from lemon, popsicle sticks, refined shea butter, dropper, measuring cups and spoons.

Fig. 11. Prepare materials needed

In a small plate put 15g/ 10g/ 5g of wax (soy wax, palm wax, beeswax). Add 2 teaspoons of pigment.

Fig. 12. Put wax and pigment in the pan

In a double boiler, put the plate with wax and pigment to melt it. Mix it with a popsicle stick to make the wax pigment well combined.

Fig. 13. Melt the wax in double boiler

When it is well combined, transfer it to the crayon molder.

Fig. 14. Transfer it in the molder

Air dry the crayon for about 30 minutes to 1 hour.

Table 1
A table of data from drop test to measure the durability of soy wax, palm wax, and beeswax

Durability Test	Soy Wax			Palm Wax			Beeswax		
Trials	5g	10g	15g	5g	10g	15g	5g	10g	15g
Mass of Weight (kg)									
Number of Break Resistant									
Number of Drops									
Drop Survival Rate (DSR)									
Damage Index (DI)									

Fig. 15. Air dry the crayon

C. Respondents of the Study

No other respondent, aside from the researchers, were involved during the experimental process. The researchers served as the primary implementers and observers throughout the entire experimentation. They were responsible for preparing the materials, conducting the procedures, recording the data, and analyzing the results. Since the nature of the study is experimental, direct participation from external respondents or participants was not necessary. Instead, the researchers ensured that all experimental conditions were carefully controlled and systematically observed to maintain accuracy, reliability, and consistency in the results.

3. Table

A. Data Gathering

The following data gathered and computed are arranged in the following table for simpler and easier process of calculation and analysis of variance:

Table 2 shows the damage index scoring criteria used to evaluate the durability of eco-crayons made from soy wax, palm wax, and beeswax.

Table 2
A table of damage index for scoring criteria of durability test for the three waxes

Damage Index Scoring Criteria for Durability Test	
0	Excellent durability
1	Very high durability
2	High durability
3	Moderate durability
4	Low durability
5	Very poor durability

Scores range from 0 to 5, with lower values indicating greater resistance to breakage. During the drop test, each crayon was released from a fixed height, and the extent of damage after impact determined its score. A rating of 0 signifies *excellent durability* with no visible damage, while 1–2 denote *high durability* with minor surface marks. A score of 3 indicates *moderate durability*, and 4–5 reflect *low to very poor durability*, showing cracks or complete breakage. This index provided a clear, quantitative basis for comparing wax performance and for subsequent ANOVA analysis of durability differences among the samples (Alexander, Rahman, & Bakar, 2021).

Table 3 presents the results of the colorimeter test conducted to measure the color vibrancy of eco-crayons formulated with soy wax, palm wax, and beeswax using pigments extracted from rose (red), butterfly pea (blue), and sunflower (yellow). The colorimeter provided quantitative values for perceptual lightness (L), red-green axis (a), and yellow-blue axis (b),

Table 3
A table of data from colorimeter test to measure the color vibrancy of primary colors such as red, blue, and yellow

RED COLOR									
Color Vibrancy Test	Soy Wax			Palm Wax			Beeswax		
Trials	5g	10g	15g	5g	10g	15g	5g	10g	15g
Perceptual Lightness (l)									
Red-Green axis (a)									
Yellow-Blue axis (b)									
Vibrancy (C)									
BLUE COLOR									
Trials	5g	10g	15g	5g	10g	15g	5g	10g	15g
Perceptual Lightness (l)									
Red-Green axis (a)									
Yellow-Blue axis (b)									
Vibrancy (C)									
YELLOW COLOR									
Trials	5g	10g	15g	5g	10g	15g	5g	10g	15g
Perceptual lightness (l)									
Red-Green axis (a)									
Yellow-Blue axis (b)									
Vibrancy (C)									

which together determine the overall color vibrancy (C) of each sample.

B. Data Analysis

In analyzing the data, this research will use the one-way ANOVA test. The researcher has decided to choose one-way ANOVA as a statistical tool in order to interpret whether to reject or fail to reject the null hypothesis of the study. The analysis of variance is essentially designated for research whose experimentation processes include three or more conditions (JMP n.d.). In this statistical tool, the alpha value of the analysis is predetermined, 0.05. The F critical value and the variance within and between groups will also be identified.

The table presents the formulas to be used in evaluating the durability of soy wax, palm wax, and beeswax through the Drop Weight Testing method. It includes the Drop Survival Rate (DSR), which measures the percentage of drops without failure, and the Damage Index (DI), which calculates the average damage sustained per drop (Habibollahi Najaf Abadi, Herrmann & Modarres, 2023). These formulas help assess the strength and resistance of the wax samples under repeated impact.

The table presents the formula to be used in the colorimeter test to determine the color vibrancy (*C*) of pigments extracted from flowers. It illustrates that color vibrancy is calculated using the values of *a* and *b,* which represent the chromatic components of color on the red-green and yellow-blue axis, respectively. This formula helps quantify the intensity and purity of the color produced by the natural pigments.

Table 4
The table shows the formula of one-way ANOVA test for the computation of durability test and color vibrancy

FORMULA OF ONE-WAY ANOVA TEST
$F = \frac{MS_{\text{between}}}{MS_{\text{within}}}$

Table 5
The table shows the formula of the durability test of the soy wax, palm wax, and beeswax for the drop survival test and damage index of the waxes

FORMULA FOR DURABILITY TEST (Drop Weight Testing)
$DSR = \frac{Number\ of\ successful\ drops\ without\ failure}{Total\ planned\ drops}\ x\ 10($
Damage Index
$DI = \frac{Total\ damage\ score\ across\ test}{Number\ of\ drops}$

Table 6
The table shows the formula of color vibrancy test for the pigments that are extracted from the flowers

FORMULA FOR COLOR VIBRANCY TEST (Colorimeter Test)
$C = \sqrt{a^2 + b^2}$

The data gathering procedures were systematically structured to collect accurate and reliable measurements necessary to assess the effectiveness of eco-crayons in terms of durability and color vibrancy. The chapter clearly outlines how the data were obtained using standardized experimental methods such as drop testing for durability and colorimeter testing for pigment vibrancy. Each test was carefully designed to observe how different wax types (soy wax, palm, and beeswax) and varying concentrations affected the performance of the formulated crayons.

The gathered data were organized into detailed tables to ensure clarity and comparability among the three was groups. The recorded data serve as the foundation for statistical analysis using one-way ANOVA, which helped determine whether the differences observed among the wax formulations were statistically significant. Overall, the data gathering process demonstrates a rigorous and methodical approach, ensuring that the information collected is valid, quantifiable, and aligned with the research objectives.

4. Figures

A. Data Collection and Analysis

This chapter presents the results obtained from the experimental tests conducted on eco-crayons formulated with different natural waxes soy wax, palm wax, and beeswax and botanical pigments extracted from rose (red), butterfly pea (blue), and sunflower (yellow). The evaluation focused on durability, measured through a drop test, and color vibrancy, assessed using a colorimeter. These parameters were selected to determine how the chemical and physical properties of each wax influence the mechanical strength and chromatic quality of the eco-crayons. The results are organized in statistical tables and bar graphs, supported by the interpretation of findings in connection with the study's hypotheses and reviewed literature.

The results affirm the first hypothesis that different wax types significantly influence the durability and color vibrancy of eco-crayons, though statistical analysis (ANOVA) showed no significant difference at the 0.05 level. The physical and chemical distinctions among the waxes explain the observed trends: beeswax provided strength and stability, soy wax contributed brightness and smoothness, and palm wax offered moderate glide but limited resilience. Durability Test Results

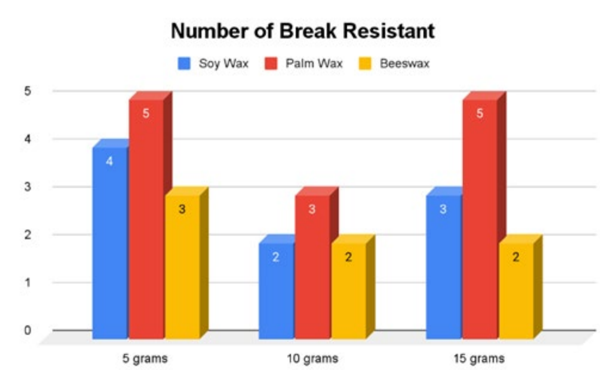

Fig. 16. A graph showing the break resistant results of the 3 waxes such as soy wax, palm wax and beeswax

These outcomes are consistent with the reviewed studies on natural wax behavior and pigment interaction, thereby supporting the study's objective of identifying effective, sustainable, and non-toxic materials for eco-crayon production.

The data above present the results of the durability test on soy wax, palm wax, and beeswax using drop weight testing. Palm wax exhibited the highest break resistance, indicating it can withstand greater stress before breaking. However, beeswax demonstrated superior overall durability. Based on the Drop Survival Rate (DSR) and Damage Index (DI), beeswax achieved a 100% DSR and the lowest DI of 2, reflecting excellent impact resistance and minimal damage. In contrast, soy wax and palm wax showed higher DI values and lower DSRs, making them more susceptible to cracking or breaking. Overall, while palm wax resists breaking under stress, beeswax maintains the greatest integrity during repeated drops, making it the most durable of the three.

B. Color Vibrancy Test Results

The graph illustrates the red-green axis (a) values of red pigments extracted from roses for eco-crayons made with soywax, palm wax, and beeswax at concentrations of 5g, 10g, and 15g. The results show that palm wax consistently produced higher red intensity across all concentrations, with a peak at 10g (14.6), followed closely by soy wax (10.7) and beeswax (12.3). Medium concentrations (10g) generally yielded the highest red vibrancy, suggesting that an optimal wax-to-pigment ratio enhances color saturation. Beeswax showed lower a-values, indicating reduced pigment visibility compared to the other waxes. Overall, the data indicate that both wax type and concentration influence the red hue intensity in eco-crayons, with palm wax demonstrating the strongest enhancement of red vibrancy.

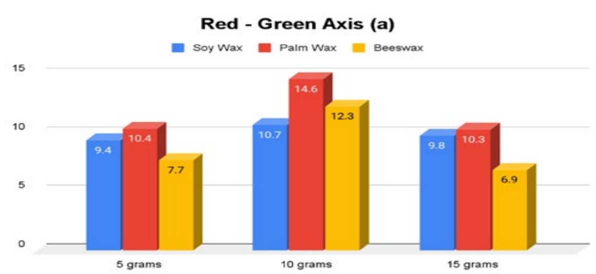

Fig. 17. A graph showing the red-green axis (a) of color vibrancy results of red pigments that are extracted from roses

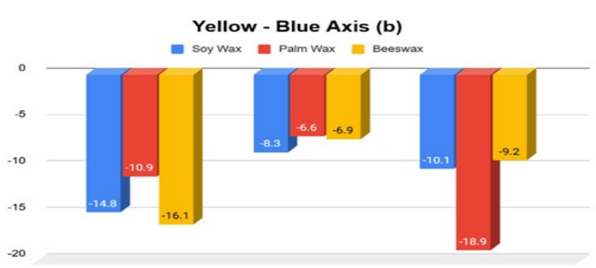

Fig. 18. A graph showing the yellow-blue axis (b) of color vibrancy results of blue pigments that are extracted from butterfly pea

The results of the color vibrancy test for blue pigments show that the interaction between natural pigments and different wax formulations significantly affected the visibility, depth, and intensity of the blue color in eco-crayons. Data trends reveal variations in lightness, chromatic coordinates, and vibrancy, reflecting differences in each wax's ability to retain and project the pigment. Graphs support these findings, with some waxes producing deeper, more saturated blues, while others yield lighter or less intense shades. Overall, both the type and amount of wax play a key role in color retention and brightness, emphasizing the importance of wax selection for achieving high visual quality in eco-friendly crayons.

The bar graph in Figure 19 illustrates the yellow-blue axis (b) values for yellow pigments extracted from sunflowers, formulated with three different waxes: soy wax, palm wax, and beeswax, across three concentrations (5 g, 10 g, and 15 g). At 5 grams, palm wax and soy wax exhibit similar vibrancy (30.3 and 30.2, respectively), while beeswax shows a slightly lower value (27.6). Increasing the concentration to 10 grams, all waxes show an increase in b values, with palm wax peaking at 32.8, beeswax at 32.3, and soy wax at 29.9, indicating enhanced yellow intensity. At 15 grams, the vibrancy decreases across all waxes, with soy wax at 25.5, palm wax at 22.3, and beeswax at 22.5, suggesting a potential saturation effect that reduces the yellow-blue axis values at higher pigment concentrations. Overall, the graph indicates that the wax type and pigment concentration influence the yellow vibrancy of sunflower-based eco-crayons, with palm wax generally producing the highest b values at moderate concentrations.

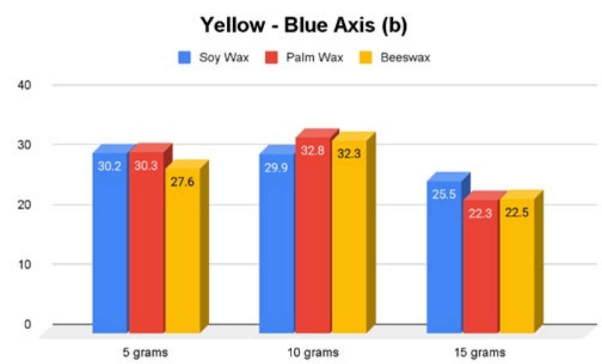

Fig. 19. A graph showing the yellow-blue axis (b) of color vibrancy results of yellow pigments that are extracted from sunflower

5. About References

A. Synthesis

The reviewed literature and studies collectively emphasize the increasing global movement toward the development of sustainable, non-toxic, and environmentally friendly art materials, particularly in the production of crayons. Previous researchers have extensively explored the substitution of petroleum-based ingredients with natural pigments and biodegradable waxes to address both health and environmental concerns associated with traditional paraffin-based crayons. Studies conducted by Neddo (2020) and Becchi (2021), underscore the educational and ecological value of using natural art materials, promoting creativity while fostering environmental consciousness among young learners. Similarly, the botanical insights of Hickey and King (2000) have contributed to identifying flower species with high pigment potential suitable for crayon formulation.

Empirical investigations have further validated the practicality of utilizing natural waxes in crayon production. Research by Romero et al. (2021) and Alexander et al. (2023), confirmed that soy wax and beeswax exhibit desirable properties such as durability, smooth texture, and stability, making them viable alternatives to paraffin. Complementary findings by Arisgaldo et al. (2025), Saldia et al. (2024), and Adaniel et al. (2023), demonstrated that natural pigments like paprika, annatto, and turmeric, when combined with beeswax or soy wax, produce crayons with satisfactory color intensity, durability, and user acceptance. Moreover, Banias and Ciudad (2023), identified viable plant-based red pigments that exhibit strong chemical compatibility with natural waxes, further supporting the potential for sustainable crayon formulation.

Despite these advancements, a notable research gap persists. Most existing studies have primarily focused on the use of single wax types or specific natural pigments, without conducting a comprehensive comparative analysis of multiple natural wax bases or exploring the potential of locally available botanical flowers as pigment sources. Furthermore, limited attention has been directed toward the educational integration of eco-crayon production, particularly its role in promoting environmental literacy and sustainability awareness within early childhood and elementary education contexts.

In addressing these gaps, the present study seeks to formulate and evaluate eco-crayons derived from botanical flower pigments, specifically rose, butterfly pea, and sunflower combined with soy wax, beeswax, and palm wax. Through comparative analysis in terms of color vibrancy and durability, this research aims to identify the most effective wax composition for sustainable crayon production. Additionally, by situating the study within the context of educational sustainability, it contributes not only to material science but also to pedagogical innovation demonstrating how eco-crayon development can serve as both a scientific endeavor and an educational tool for fostering environmental awareness among learners.

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