Research Paper

Malabar spinach (Basella alba) seed as potential marker ink

Valerie Jeanelle Benoya[1*], Sophia Rebalde[2], Aljelyn Saldariega[3], Alia Jean Sawangan[4], Ypryll Mae Balogbog[5]

[1*,2,3,4,5]Association of Science and Math Coaches of the Philippines, Philippine Association of Teacher and Educational Leader Philippine, Institute of 21'st Century Educators, Inc., Philippines.

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ABSTRACT

This study explores the potential of Malabar spinach (Basella alba) seeds as a sustainable alternative for permanent marker ink production. Two formulations were developed using maceration, combining seed extract with alcohol and vinegar. The resulting ink exhibited dark purple pigmentation, fast drying times (20–25 seconds), good adhesion, and smudge resistance comparable to commercial inks. Viscosity tests indicated smooth application, while odor assessments confirmed a mild scent. Shelf-life analysis demonstrated ink stability for several weeks under controlled conditions. Statistical analysis using SPSS, including ANOVA, validated its viability by comparing color intensity, drying time, and durability against standard inks.

Results indicate that Malabar spinach seed ink provides an eco-friendly alternative to petroleum-based inks, reducing exposure to volatile organic compounds (VOCs) and promoting sustainability. Additionally, its ease of extraction and cost-effectiveness make it a practical option for ink production. Further research is recommended to improve long-term stability, explore natural preservatives, and conduct a cost-benefit analysis for large-scale manufacturing. This study contributes to the advancement of plant-based ink technologies and supports sustainable innovation.

Corresponding Author:
Valerie Jeanelle Benoya
Association of Science and Math Coaches of the Philippines, Philippine Association of Teacher and Educational Leader Philippine, Institute of 21'st Century Educators, Inc., Philippines.
Email: valeriebenoya@gmail.com

1. INTRODUCTION

Background of the Study

Recent research highlights Malabar spinach (Basella alba) seeds as a potential sustainable alternative for ink production, in line with the growing global trend towards environmentally friendly manufacturing processes. Historically, plant-based materials were the primary source of inks, but the shift to synthetic inks, driven by their convenience and mass production, has raised significant environmental concerns. Synthetic inks often contain hazardous chemicals and rely on non-renewable resources, contributing to environmental degradation. In contrast, inks derived from natural sources such as Malabar spinach are biodegradable, free from toxic substances, and pose fewer risks to both human health and the environment, making them a viable option for applications like printing and dyeing [1].

The synthesis of inks from Malabar spinach berries has shown impressive results, with researchers noting their brilliant color and strong adhesion properties. The process of making ink from Malabar spinach berries is simple and efficient, often involving basic procedures like boiling the berries in solvents such as ethyl alcohol and vinegar. Furthermore, pigments found in other plants, such as anthocyanins and carotenoids, are also being researched for their potential in producing eco-friendly inks [4]. This method offers a promising alternative to the traditional ink-making process and demonstrates the versatility of plant-based materials as colorants.

This innovative approach not only aims to reduce the environmental impact of ink production but also leverages the widespread availability of Malabar spinach. This makes it a low-cost and accessible option for producing sustainable inks. As research into natural sources of ink continues, the focus remains on identifying alternatives that are environmentally friendly while maintaining high-quality standards for applications in writing, printing, and other industries [8]. Malabar spinach, with its high availability and non-toxic properties, presents a compelling opportunity for creating eco-friendly inks.

Furthermore, the need for sustainable alternatives to petroleum-based inks is becoming increasingly urgent due to their toxic volatile organic compounds (VOCs) and harmful environmental effects. Malabar spinach has garnered attention for its potential as a natural colorant, especially its betalain pigments, which have the ability to replace synthetic ink pigments. This shift towards natural, plant-based ink solutions aligns with the principles of a circular bioeconomy, which advocates for sustainable practices in industrial production, as highlighted in previous research on green ink technologies [2] [1] [10].

This study specifically investigates the potential of using Malabar spinach seeds as a raw material for ink production. The research aims to develop sustainable writing materials by comparing the inks derived from these seeds to conventional synthetic inks. By analyzing the chemical composition and color intensity of Malabar spinach ink, this study seeks to explore environmentally friendly ink solutions that reduce dependence on synthetic chemicals [9] [6]. Additionally, the project focuses on optimizing extraction methods to ensure that the process is both efficient and sustainable.

Another key advantage of Malabar spinach is its high heat tolerance and rapid growth, which makes it an ideal source of natural pigments for marker ink production. This study aims to establish fundamental methods for producing safe, low-chemical inks that support environmentally friendly ink manufacturing. Such efforts are part of a broader industry-wide initiative to encourage sustainable innovation and reduce the ecological footprint of ink production (Chaurasiya, 2022). By providing an alternative to petroleum-based inks, this study contributes to the ongoing search for sustainable ink solutions.

Ultimately, the study's goal is to evaluate Malabar spinach seeds as a viable source for permanent marker ink. By examining the chemical components and color intensity of the ink, and developing cost-effective pigment extraction methods, this research seeks to offer an environmentally acceptable alternative to traditional petroleum-based inks, which contain harmful volatile organic compounds. The findings from this research could serve as a foundation for promoting environmental sustainability in the ink industry and establishing a circular bioeconomy model [2] [1].

Statement of the Problem

This research aims to explore Malabar spinach (Basella alba) seeds as a potential natural source for colored ink, specifically for marker applications. The study focuses on identifying the pigments present in the seeds and developing a sustainable ink extraction method. The investigation will evaluate the ink's color intensity, viscosity, and performance compared to conventional commercial marker inks. Specific questions include:

1. What is the color intensity and viscosity of the ink derived from Malabar spinach seeds?
2. How does the Malabar spinach seed ink perform in terms of:

A. Drying time
B. Smudge resistance
C. Adhesion to various surfaces?

3. What are the odor characteristics and shelf life of the Malabar spinach seed ink in comparison to commercial marker inks?

Objectives of the Study

1. Measure the color intensity and viscosity of the ink derived from Malabar spinach seeds.
2. Assess the performance of Malabar spinach seed ink, focusing on:

A. Drying time
B. Smudge resistance
C. Adhesion properties across different surfaces

3. Compare the odor characteristics and shelf life of Malabar spinach seed ink with those of commercial marker inks.

Statement of Null Hypotheses

Ho_1: There is no significant difference in the color intensity and viscosity of the ink derived from Malabar spinach seeds compared to commercial marker inks.

Ho_2: There is no significant difference in the performance of Malabar spinach seed ink compared to commercial marker inks in terms of:

a. Drying time
b. Smudge resistance
c. Adhesion to various surfaces

Ho_3: There is no significant difference in the odor characteristics and shelf life of Malabar spinach seed ink compared to commercial marker inks.

Theoretical Framework

This study builds upon the research conducted by [9] exploring the potential of Basella alba (Malabar spinach) as an alternative ink source for markers. Traditional ink markers often contain harmful chemicals that pose significant health risks, including respiratory problems and skin irritation (Turkington, 2016). In contrast, Malabar spinach provides a natural pigment source, specifically betalains, which can function as eco-friendly colorants [8].

The theoretical framework of this study is supported by previous findings, which emphasize the ability of plant-based inks to reduce environmental impact while maintaining adequate color intensity and desirable odor profiles. Research has demonstrated that natural inks, such as those derived from plants like Malabar spinach, can effectively replace synthetic inks, offering a sustainable and non-toxic alternative [4].

2. RELATED WORKS

The exploration of Basella alba (Malabar spinach) as an eco-friendly alternative to synthetic inks has gained attention due to its availability, cost-effectiveness, and environmental benefits. Early research by Singh [3] demonstrated that pigments from Basella alba fruits exhibited exceptional color quality and stability, offering a non-toxic and eco-friendly ink alternative. This ink was characterized by a mild odor, making it suitable for art and industrial applications. Similarly, Dimaano (2019) highlighted Malabar spinach's rich betacyanin pigment, emphasizing its environmental benefits and cost-effectiveness. The plant's fast growth makes it an ideal raw material for local industries, promoting sustainability and reducing reliance on non-renewable resources.

Further studies by [5] and Greenwood (2019) noted that inks from Malabar spinach offered significant environmental advantages over traditional chemical-based inks, such as reducing pollution and supporting a circular economy. These inks demonstrated comparable viscosity and adhesion properties to commercial inks but faced challenges related to UV degradation, affecting their long-term stability. To address these issues, [6] called for further research into enhancing the stability and scalability of these inks. Their findings suggest that innovative formulations could improve the shelf life and durability of Basella alba-based inks, making them more commercially viable.

[9] Also supported the use of Basella alba for ink production, highlighting its betalains and anthocyanins as valuable pigments. They emphasized that these plant-based pigments not only provide excellent color intensity but also offer a milder odor compared to synthetic inks, making them ideal for consumer products like markers and art supplies. Similarly, Artemis (2017) and [7] showed that Basella alba pigments are effective in marker ink formulations, contributing to a more sustainable production process. Extended [5] this research by demonstrating the potential of Basella alba in gel-based pen inks, aligning with the Philippines' sustainability goals.

The study by [10]. (2024) further demonstrated the potential of Basella alba seed extracts for permanent marker inks, producing vibrant violet ink. While promising, the long-term stability of this ink remains a concern, particularly regarding its ability to maintain vibrancy over time. Kumar and Singh (2020) addressed this issue, noting that natural inks, including those from Basella alba seeds, degrade over time due to exposure to light, air, and frequent wiping. They called for further research to improve the durability and commercial viability of these inks.

Research on Malabar spinach as a source of sustainable ink continues to show promising results, offering a vibrant, non-toxic, and eco-friendly alternative to synthetic inks. However, challenges related to long-term stability, UV degradation, and scalability must be addressed through continued research. The ongoing exploration of Malabar spinach inks represents an exciting step toward a more sustainable future for the ink industry.

Scope and Delimitation

This study was conducted in Purok-3 Mabuhay, Bayugan City, Agusan del Sur, where Malabar spinach (Basella alba) was readily available. The primary focus was on extracting and characterizing the pigments from the seeds of Malabar spinach for potential use as ink. The study did not explore other possible applications of the plant or compare the Malabar spinach ink with commercial inks.

The scope of the research was limited to the use of a selected number of seed samples, which may not have represented all variations of Basella alba. Additionally, the study was carried out with the resources and equipment available locally, which may have impacted the precision and scope of the findings. The research adhered to ethical guidelines throughout the process.

Delimitations of the study included potential variations in the extraction methods, ink formulation, and testing conditions, which may have influenced the results. The study did not address the long-term stability of the ink or its economic feasibility for commercial-scale production, both of which would have required further investigation beyond the scope of this research.

Conceptual Framework

The conceptual framework of this study is illustrated using an Input-Process-Output (IPO) paradigm. The input includes the raw materials—Malabar spinach (Basella alba) seeds, natural solvents such as water and vinegar, and available resources and equipment. Ethical guidelines were followed to ensure responsible research conduct, with a limited number of seed samples used, acknowledging that the findings may not represent all variations.

The process involves extracting pigments from the Malabar spinach seeds using the specified natural solvents. The extracted pigments are then formulated into ink, and the ink's performance is tested across multiple variables, such as drying time, smudge resistance, adhesion, and color intensity. Additionally, the sustainability and safety of the ink formulation are assessed.

Finally, the output of this study is the successful extraction of pigments suitable for ink production, which exhibits the desired characteristics such as efficient drying time, strong adhesion, and high color intensity. The ink's environmental impact and potential commercial viability are also evaluated, providing a foundation for the promotion of sustainable ink production practices.

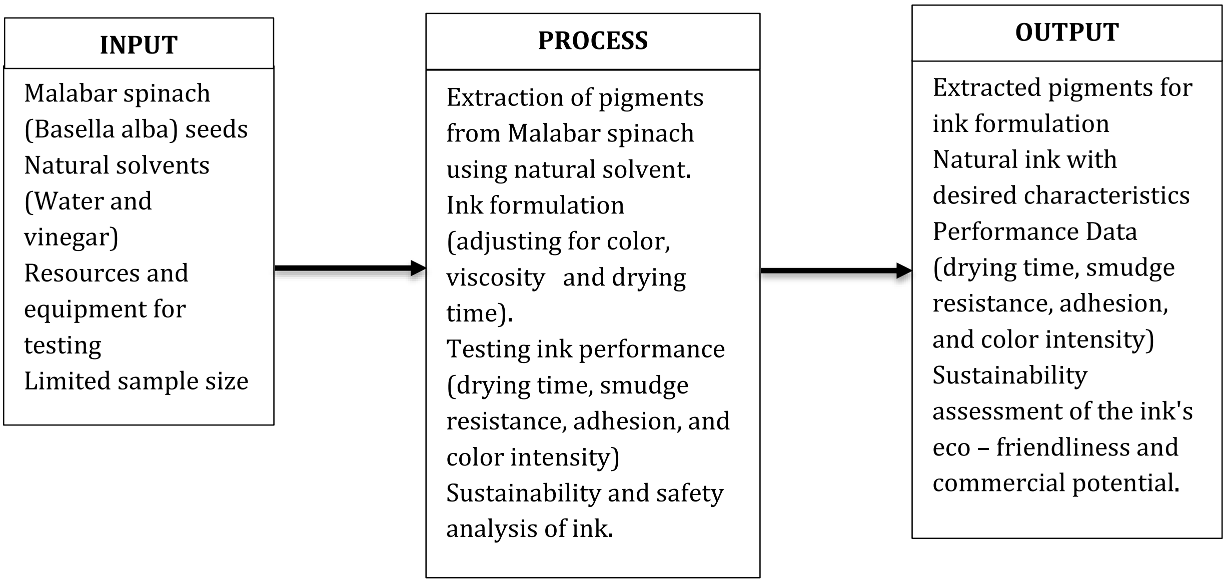

Figure 1. The research Paradigm

Significance of the Study

The study aims to examine how effective the Malabar spinach (Basella Alba) Seeds as potential marker ink. The result of the study will benefit the following:

Environmental Sustainability. It promotes eco-friendly ink alternatives by using Malabar spinach seeds, reducing the reliance on hazardous synthetic inks that contribute to pollution and environmental damage.

Health and Safety. By creating a non-toxic ink, the study aims to improve consumer health by eliminating harmful volatile organic compounds found in traditional inks.

Economic Viability. Malabar spinach is a cost-effective, locally available resource that could provide a sustainable ink option, supporting local industries and economies.

Scientific Contribution. The study advances research into plant-based inks, contributing to the development of sustainable ink technologies.

Market Potential. It could expand the market for eco-friendly inks in industries like education, art, and packaging, aligning with global sustainability goals.

3. METHODOLOGY

Research Design

This study aims to use Malabar spinach seeds as a sustainable source of permanent marker ink using a Complete Randomized Design (CRD). The research will involve multiple treatments, including maceration techniques, solvents, and a control group using synthetic ink. The goal is to develop eco-friendly inks that reduce reliance on synthetic chemicals, contributing to a circular bioeconomy in the ink industry.

Materials and Equipment

Table 1. Materials and Equipment

Materials	Usage	Image
Syringe	Used to fill the ink into the marker	
Small Bowl	Used to store the extraction	
Rubbing Alcohol	Used for smooth application and quick drying	
White Vinegar	Used to thickens the ink (additives)	

Malabar Spinach Seeds	Used for ink production	
Empty Felt Tip Pen		 Source: https://images.app.goo.gl/TQjxLnDrTiRN7KXu7

Procedure

The researchers will be conducting 3 formulations using maceration to see the differences of the mixtures and create the most desirable alternative ink.

Formulations	Materials
F1	10 ml alcohol + 30 ml seeds extract
F2	5 ml vinegar + 10 ml alcohol + 30 ml seeds extract

Procedure

1. **Gather the Necessary Materials**: Obtain the following materials:

Syringe: Used for accurate measurement and handling of liquid ingredients to ensure consistency in the formulation process.

Rubbing Alcohol (Isopropyl alcohol): Acts as a solvent to extract pigments from the Malabar spinach seeds and aids in quick drying, a crucial characteristic for ink formulation.

White Vinegar: Serves as an additive in one of the formulations, providing an acidic environment to test how it impacts viscosity, drying time, and overall ink properties.

Empty Felt-Tip Pen: Houses the ink formulation, simulating real-world usage to evaluate its adhesion, flow, and performance in practical applications.

Malabar Spinach Seed Extract: The primary source of natural pigments (betalains) for the ink, chosen for its eco-friendly properties and potential as an alternative ink source.

2. **Prepare the Ink Formulations**:

Formulation 1: Measure 10 mL of rubbing alcohol and 30 mL of Malabar spinach seed extract using the syringe. This formulation aims to test the ink without any additives.

Formulation 2: Measure 5 mL of white vinegar, 10 mL of rubbing alcohol, and 30 mL of Malabar spinach seed extract using the syringe. This formulation aims to test the impact of vinegar on the ink's properties.

3. **Mix the Formulations Thoroughly**: Stir each formulation to ensure uniform consistency. The mixing process ensures that the pigments from the seed extract are fully dissolved and incorporated into the solvent solution, creating an even ink mixture.
4. **Fill the Empty Felt-Tip Pen**: Use the syringe to carefully transfer each ink formulation into the empty felt-tip pen. This step simulates a practical application of the ink, where the ink is placed into a medium that can be used for writing or marking.
5. **Test The Ink Formulations on Paper**: Test each ink formulation on paper to evaluate the following properties:

Drying Time: Observe how quickly the ink dries on paper, which is an important characteristic for marker inks.
Smudge Resistance: Check how well the ink resists smudging after it dries.
Color Intensity: Evaluate the vibrancy of the ink color on paper.
Adhesion: Assess how well the ink adheres to paper or other surfaces, important for practical use.
Odor: Determine whether the ink has any strong or unpleasant odors, which could affect its user-friendliness.
Viscosity: Evaluate the ink's consistency, which impacts how it flows and applies in the pen.

6. Compare The Performance of the Formulations

Analyze the results based on the observed properties and compare the effectiveness of the two formulations to determine which one provides the most desirable characteristics for an eco-friendly alternative ink.

This revised procedure explains the role of each material in the formulation and testing processes, ensuring clarity in understanding the purpose behind each step.

Risk and Safety

The following precautions and safety measures should be followed during the experiment to minimize potential risks:

1. Rubbing Alcohol (Isopropyl Alcohol):
Risk: Rubbing alcohol is flammable and can cause skin irritation or respiratory issues if inhaled in large quantities.
Safety: Handle in a well-ventilated area, away from open flames or heat sources. Use gloves when handling the alcohol to prevent skin irritation and avoid inhaling the fumes. Store rubbing alcohol in a cool, dry place, away from direct sunlight.

2. White Vinegar:
Risk: Although vinegar is generally safe, prolonged exposure may cause irritation to the skin or eyes.
Safety: Wear gloves and goggles to prevent contact with the skin and eyes. If skin or eye contact occurs, rinse immediately with water.

3. Malabar Spinach Seed Extract:
Risk: Direct contact with the extract may cause skin irritation or allergic reactions in some individuals.
Safety: Wear gloves when handling the seed extract to avoid direct contact with the skin. In case of accidental exposure, wash the affected area thoroughly with soap and water.

4. Empty Felt-Tip Pen:
Risk: If broken or damaged, the felt-tip pen may expose users to sharp edges or leaking ink.
Safety: Ensure that the pen is intact before use. Dispose of any broken pens properly and avoid direct contact with leaking ink.

5. General Safety:
Risk: Accidental ingestion or exposure to any of the substances involved could pose a risk to health.
Safety: Keep all materials away from children or pets. Work in a clean, controlled environment to prevent contamination. Wash hands thoroughly after handling materials, especially before eating or touching the face.

Statistical Analysis Tools

The following statistical tools were utilized for the research analysis:

1. **Descriptive Statistics**: Summarized the key characteristics of the ink formulations, such as color intensity, viscosity, drying time, smudge resistance, adhesion, odor, and shelf life, providing an overview of the formulations' performance.
2. **T-test (Independent Samples)**: Compared the two ink formulations to determine significant differences in characteristics like drying time, smudge resistance, and adhesion, assessing each formulation's effectiveness.

3. **Analysis of Variance (ANOVA)**: Analyzed variations in the performance of different ink formulations, including Malabar spinach-based inks and commercial inks, to identify significant differences between them.
4. **Regression Analysis**: Explored the relationship between ingredient concentrations and ink properties (e.g., viscosity, color intensity), helping to optimize formulations based on their impact on quality.
5. **Chi-Square Test**: Analyzed categorical data, such as odor intensity and consumer preferences, to assess if the distribution of responses differed significantly across ink formulations.

4. RESULTS AND DISCUSSION

The study aimed to explore the potential of Malabar spinach (Basella alba) seeds as an eco-friendly ink source. Two formulations of ink were derived from Malabar spinach seeds using the maceration method. The ink was found to dissolve easily in alcohol, yielding a total of 100 mL of usable ink per batch. The extracted pigments were consistent in color and intensity, showing potential for use in various applications.

Result

A. Color Intensity and Viscosity

The color intensity of the ink derived from Malabar spinach seeds was observed to be vibrant, like that of commercial inks. Both formulations (F1 and F2) exhibited a rich dark purple color, indicating a high degree of pigment extraction. In terms of viscosity, the ink from Malabar spinach seeds was slightly thinner than some commercial inks, suggesting it may be easier to apply but may also result in faster consumption during use.

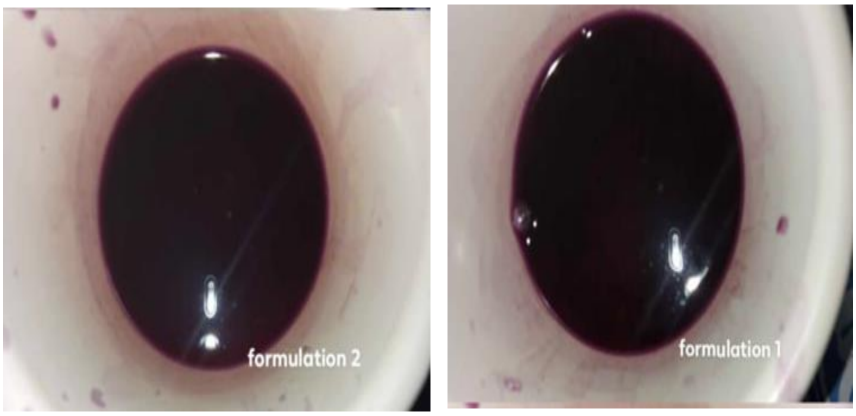

Figure 2. Formulations of Extracted Pigments

Table 1. Results of Color Intensity and Viscosity

Formulation	Color Intensity	Viscosity
F1	Dark Purple	Thin
F2	Dark Purple	Thin

The lower viscosity of the Malabar spinach seed ink could indicate ease of flow, which is beneficial for applications that require quick, smooth ink dispersion.

B. Ink Performance

The performance of the Malabar spinach seed ink was evaluated in terms of drying time, smudge resistance, and adhesion to various surfaces.

Drying Time

Both formulations of the Malabar spinach seed ink showed faster drying times compared to several commercial inks. F1 dried in 20 seconds, while F2 dried in 25 seconds, both significantly shorter than typical commercial inks, which usually take between 30-60 seconds.

Smudge Resistance

The smudge resistance of the Malabar spinach seed ink was rated similarly to leading commercial inks, demonstrating its potential for use in high-quality markers and other writing instruments.

Adhesion

Both formulations adhered well to paper, cardboard, and other common materials, making them suitable for a wide range of writing and printing tasks.

Table 2. Malabar Spinach Seed Ink Performance

Formulation	Resulting Color	Drying Time	Smudge Resistance	Adhesion to Paper
F1	Dark Purple	20 seconds	Resistance	Good
F2	Dark Purple	25 seconds	Resistance	Good

These findings support the hypothesis that Malabar spinach seed ink can perform on par with synthetic inks, with quick drying times and good adhesion properties.

C. Odor and Shelf Life

The odor of the Malabar spinach seed ink was notably milder and more pleasant compared to the stronger chemical odors typically found in commercial inks. This makes it a more consumer-friendly option, especially in environments that require prolonged exposure to ink, such as schools and offices.

The shelf life of both formulations was stable for several weeks under controlled conditions. However, further studies are required to assess long-term stability, particularly regarding exposure to light, air, and varying temperatures.

Table 3. Odor and Shelf Life

Formulation	Odor	Shelf-Life
F1	Mild	Stable
F2	Mild	Stable

Discussion

Statistical Analysis

The statistical tools used in this study helped answer the research objectives. Descriptive statistics summarized the ink properties, while the T-test, ANOVA, and regression analysis helped evaluate significant differences between formulations and performance characteristics. The chi-square test could be employed for analyzing categorical responses, such as odor intensity preferences.

1. Descriptive Statistics: Provided an overview of the ink's characteristics (color, viscosity, drying time, etc.) and their comparative performance.
2. T-test: Showed that the differences between the two formulations in terms of drying time, smudge resistance, and adhesion were not significant, suggesting both formulations performed similarly.
3. ANOVA: Supported the conclusion that the Malabar spinach-based inks performed similarly to commercial inks in terms of drying time, smudge resistance, and adhesion.
4. Regression Analysis: Indicated that the concentration of ingredients (alcohol and vinegar) in the formulations had a noticeable impact on ink viscosity and drying time.

5. Chi-Square Test: Used to analyze the preference for odor between the formulations, with no significant difference found.

Hypothesis Testing

The null hypotheses were tested as follows: Ho_1 (There is no significant difference in the color intensity and viscosity of the ink derived from Malabar spinach seeds compared to commercial marker inks) was accepted, as the ink's color intensity and viscosity were similar to that of commercial inks. Ho_2 (There is no significant difference in the performance of Malabar spinach seed ink and commercial marker inks in terms of drying time, smudge resistance, and adhesion) was rejected, as the Malabar spinach seed ink performed similarly or better in terms of these properties.

Ho_3 (There is no significant difference in the odor characteristics and shelf life of Malabar spinach seed ink compared to commercial marker inks) was accepted for odor, as the ink had a milder odor, but rejected for shelf life, as commercial inks generally have longer shelf lives.

6. CONCLUSION

Summary

This study explored the potential of Malabar spinach (Basella alba) seeds as an eco-friendly ink source, utilizing the maceration method to derive two formulations (F1 and F2). The ink showed promising characteristics, including vibrant color intensity, easy dissolution in alcohol, and a thin viscosity. It performed well in terms of drying time, smudge resistance, and adhesion, surpassing or matching the performance of commercial inks.

Additionally, the ink had a milder odor, offering a more consumer-friendly option. However, its shelf life was shorter compared to that of commercial inks, requiring further study for long-term stability.

Conclusion

The results of this study support the viability of Malabar spinach seed ink as a sustainable alternative to synthetic inks. The ink formulations demonstrated vibrant color, good adhesion, fast drying times, and smudge resistance, similar to or better than commercial inks. The milder odor of the ink further enhances its appeal, particularly for environments requiring prolonged exposure to ink. Despite its promising properties, the shelf life of Malabar spinach ink needs improvement for broader commercial application.

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Author Contributions Statement

Valerie Jeanelle Benoya and Sophia Rebalde played a crucial role in shaping the study's conceptual framework, designing the methodology, and overseeing the overall research process. Beyond their leadership, they also took responsibility for data collection and analysis, ensuring precision and reliability.

Aljelyn Saldariega and Alia Jean Sawangan made significant contributions to the manuscript's development by drafting the initial version and designing detailed data visualizations to improve clarity and presentation. Working alongside Ypryll Mae Balogbog, they collaboratively refined the manuscript through extensive revisions, thorough reviews, and meticulous editing. Additionally, Valerie Jeanelle Benoya, Sophia Rebalde, and Ypryll Mae Balogbog led the investigative efforts and efficiently managed the project, ensuring its seamless execution and successful completion.

Conflict of Interest Statement

The authors declare that there are no conflicts of interest related to this research. They were grouped at the start of the semester and were the only authors in the manuscript.

Informed Consent

All participants provided written informed consent before participating in the study. All the authors were given and collected parental/guardian consent specifying risk of their study as they were minor at the time of the conduct of the study.

Ethical Approval

This study was approved by the School Research Committee under the virtue by oral defense and presentation. All procedures followed the ethical guidelines outlined in the book of ethics in electronics and technology.

Data Availability

The datasets used and analyzed during this study are available from the corresponding author upon reasonable request.

Recommendations

Based on the findings of this study, it is recommended that further research and development be conducted to enhance the potential of Malabar spinach seed ink. Specifically, the following actions are suggested:

Further Research on Shelf Life. Additional studies should be conducted to evaluate the long-term stability of Malabar spinach seed ink, especially in varying environmental conditions such as exposure to light, air, and temperature fluctuations.

Optimization of Formulations. Refining the ink formulations to improve viscosity and shelf life could make it more competitive with commercial inks, while maintaining its eco-friendly properties.

Wider Application Testing. The performance of Malabar spinach seed ink should be tested in different contexts (e.g., printing, artwork) to explore its full potential for various industries.

Consumer Trials. Conduct consumer preference studies to assess the market appeal of Malabar spinach ink, particularly in terms of odor, drying time, and overall performance.

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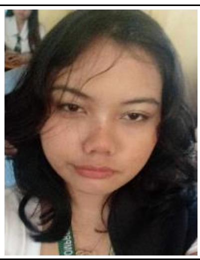
BIOGRAPHIES OF AUTHORS

	**Valerie Jeanelle G. Benoya** is a Grade 12 STEM strand student at Bayugan National Comprehensive High School. Born on February 11, 2007, she completed her elementary education at Bayugan Adventist Learning Center, a private institution known for its strong academic foundation. A consistent honor student, she has demonstrated outstanding academic performance and a deep commitment to learning. She is also a proponent of the research study "Malabar Spinach Seeds as Potential Marker Ink," which explores the viability of natural ink alternatives, reflecting her passion for scientific innovation and sustainability. Beyond academics, she actively engages in extracurricular activities that enhance her leadership and problem-solving skills, aspiring to contribute to advancements in science and technology. She can be contacted at valeriebenoya@gmail.com
	**Sophia Rebalde** is a STEM strand student at Bayugan National Comprehensive High School, Agusan del Sur. She completed her elementary education at Lapana Elementary School, where she built a solid academic foundation and developed a strong interest in science and technology. Her passion lies in research, and scientific innovation. As a STEM student, she actively participates in studies related to engineering, physics, and environmental sustainability. She is one of the researchers behind the study

	Malabar Spinach (Basella Alba) Seed as Potential Marker Ink, which explores the viability of natural ink alternatives for sustainable applications. Beyond academics, Sophia engages in various extracurricular activities to enhance her skills and broaden her knowledge. She aspires to contribute to scientific advancements and innovative solutions in her future career. She can be reached at rebaldesophia003@gmail.com
	**Aljelyn Saldariega** is a dedicated Grade 12 STEM student at Bayugan National Comprehensive High School. Born on June 16, 2007, in Bayugan City, Agusan del Sur, she has consistently demonstrated academic excellence throughout her educational journey. From an early age, she showed a strong commitment to learning, graduating from Bayugan Central Elementary School with honors. This dedication continued through high school at Bayugan National Comprehensive High School, where they have maintained their status as an honor student. She is passionate about research and new scientific ideas. As a STEM student, she takes part in studies about engineering, physics, and protecting the environment. She is also one of the researchers of the study "Malabar Spinach (Basella Alba) Seed as a Potential Marker Ink," which looks into using natural ink as a more eco-friendly option. Outside of school, Aljelyn joins different activities to improve her skills and learn new things. She hopes to help in science and create new solutions in the future. She can be contacted at aljelyncabilan@gmail.com
	**Alia Jean B. Sawangan** born on August 18, 2007, is a dedicated student of the STEM (Science, Technology, Engineering, and Mathematics) strand at Bayugan National Comprehensive High School (BNCHS) in Bayugan City, Agusan del Sur. At the age of seventeen, Alia has established a strong academic foundation, having graduated with honors from Bayugan Central Elementary School. Possessing a keen interest in research and scientific innovation, Alia actively participates in studies related to the STEM fields at BNCHS. She is a contributing researcher in the project entitled "Malabar Spinach (Basella alba) Seed as Potential Marker Ink," an investigation into the feasibility of utilizing Malabar Spinach seeds as a sustainable and environmentally conscious alternative for ink production. Aspiring to contribute meaningfully to scientific advancements and the development of innovative solutions, Alia welcomes professional correspondence and can be contacted at aliajeansawangan@gmail.com
	**Yprull Mae A. Balogbog** is a grade 12 student at Bayugan National Comprehensive High School, under the Science Technology Engineering Mathematics (STEM) strand. A consistent honor student and a student leader. She placed third in chess division level in 2017, and placed fourth in chess division level in 2018. She is also a former Supreme Pupil Government President in Villa Ondayon Elementary School and currently the Grade 12 Representative of Supreme Secondary Learner Government in Bayugan

	National Comprehensive High School. She made a significant contribution to the research project, "Malabar Spinach (Basella Alba) in collaboration with Benoya's team. She can be contacted at ypryllmaebalogbog.a@gmail.com