KAPINTA: The feasibility of coffee grounds as an alternative ink

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ABSTRACT

Approximately 2 billion cups of coffee are consumed every day. Coffee grounds used to prepare coffee in most coffee shops are thrown away, contributing to the millions of tons of landfill waste annually. Now, the reason why this is alarming is because decomposing coffee grounds and other landfill waste release methane, the second most abundant greenhouse gas. Furthermore, ink contains Volatile Organic Compounds. So, when left in landfills, wasted ink contributes to photochemical smoke and ground-level ozone emission. The main objective of this research project is to investigate the feasibility of coffee grounds as an alternative ink to commercial pens. The researchers created an ethanol mixture composed of 30 mL of water and 30 mL of ethanol which are the constant measurements in the three (3) treatments. The three (3) treatments vary in measurement regarding the number of spent coffee grounds and raw honey. The three (3) treatments undergo an evaluation procedure to see which treatment is the best to be given out to the research respondents. After thoroughly analyzing the data, the researchers rejected all three (3) null hypotheses. This is because of the significant difference between the test statistic and the critical value of the Chi-Square test. The researchers concluded that coffee grounds are a feasible material to develop an alternative and sustainable ink with all the information gathered.

I. INTRODUCTION

One of the world's valuable agricultural products is coffee. It is a member of the *Rubiaceae* family, encompassing a diverse range of species. The two main varieties of the genus, Coffea arabica, and Coffea robusta, are cultivated for commercial purposes worldwide. (Thenepalli, T. et al., 2017). According to the International Coffee Organization, Arabica exports totaled 75.32 million bags in September 2021, while Robusta exports totaled 40.98 million bags. Every day, approximately 2 billion cups of coffee are consumed. Most coffee grounds used to prepare coffee in most coffee shops are thrown away, contributing to the millions of tons of landfill waste annually. With this, decomposing coffee grounds and

other landfill waste release methane, the second-abundant greenhouse gas. The United Nations Economic Commission for Europe stated that methane has a global warming potential 28-34 times that of CO2 or Carbon dioxide. Over the past years, there have been developments and current research on reusing spent coffee grounds such as biofuel and fertilizer. However, when applied to soil, Spent coffee grounds (SCGs) will take a minimum of three months to decompose.

In addition to that, Ink in most commercially sold pens contains colorants composed of Volatile Organic Compounds (VOCs) such as methylbenzene, ethylbenzene, bromobenzene, and myxelene. Volatile Organic Compounds (VOCs) and sunlight and nitrogen oxides contribute to atmospheric photochemical reactions that cause photochemical smoke and ground-level ozone emission. Moreover, when left in landfills, volatile organic compounds and heavy metals can also cause land and water pollution. These toxic materials will continue to pollute the environment in thousands of years that it would take before they degrade.

As the researchers support current research and developments on sustainable practices, the researchers strive to produce a sustainable ink made from spent coffee grounds (SCGs). While there are existing products on reusing spent coffee grounds into valuable and sustainable products, the researchers aim to determine the feasibility of spent coffee grounds as an alternative ink that can be more efficient and less detrimental to the environment.

In line with this, the investigatory project will also be favorable to the students, manufacturers, and the Department of Environment and Natural Resources. Through this research, students at any level may develop new sustainable practices and guide them to create eco-friendly products that would lessen landfill waste. Furthermore, the study may help ink manufacturers develop alternative and more sustainable ways of manufacturing ink for printing and writing. Lastly, the study will give the government department (DENR) in-depth knowledge regarding the development of sustainable products to contribute to reducing the amount of landfill waste that emits greenhouse gasses. Consequently, the study would bring greater awareness of the problems caused by chemicals used in the manufacturing of everyday products.

II. BACKGROUND THEORY AND LITERATURE

In examining the theoretical foundations of this study, the researchers, first and foremost, determined the existing processes in which natural inks are made. To begin with, the pigments used in ink have, historically, been created with natural materials - especially plants. A book, “The Story of Ink” written by Pines C. C. (1931), shares that ink is known to have been used by the Egyptians as early as 2500 B. C. Old papyri (which are in existence today) dating back to that time were written upon with a black ink which was a mixture of lampblack and glue with a preservative to prevent decomposition. In China, the invention of ink is ascribed to Tien-Tchen, who lived between 2697 and 2597 B. C. China ink or India ink was made by the Chinese from the soot produced from the smoke of pines and the oil in lamps mixed with the isinglass of asses' skins and musk to correct the odor of the oil.

Even later on, it was observed that inks were composed of a variety of natural ingredients. Klein, U., & Spary, E. C. (2010) testified in their work, “Materials and Expertise in Early Modern Europe: Between Market and Laboratory”, that it remained the case that ink makers would put bread or onions into the mix, and as late as the nineteenth century a recipe testified that engravers' ink was made from "stones of peaches and apricots, the bones of sheep, and ivory, all well burnt". Even in modern day society, inks can be created from foraged plants and flowers. “Make Ink: A Forager’s Guide to Natural Inkmaking” is a textbook by Logan, J., & Ondaatje, M. (2018) and delivers their discovery that bark provides tannins, the inner bark layer contains pigments, sap can act as a binder; leaves and new branches, buds, flowers, fruits, berries, lichen growing on an old log, roots, stems, nuts, and the hulls of nuts - these all carry intense colors.

Gokhale et al (2004) stated that the most common extracted parts in an herbal plant for it to be a dye are seeds, flowers, berries, stems, roots, and barks. Plants' color varies for many reasons: the season it was grown, harvested, soil conditions, and many more. In the study “*Natural dye yielding plants in India”* stated that creating a natural dye requires three important steps: extraction, mordanting, and adjusting. Extraction is done by powdering the material and boiling it for a while, depending on the color of choice. Mordanting is the creation of a bond between the color and the fiber. The molecules of the dye materials are attached to the mordant. Copper tin vessels are used to brighten the color, and iron vats are used to darken the color, thus, to achieve the color of choice. According to the study of Luftinor et al (2020) *Coffee bean skin waste extraction for silk dyeing*, the coloring of yarn thread with the use of coffee bean skin coloring solution can be achieved through several procedures: cooking process, mordanting process, making dyes, colorization process, color fixation process, weaving process, and testing. Coffee bean skin is extracted or boiled with water until the boiling water is only half. After that, the colored water is filtered and ready to be used as a dye.

In the study “Application of shadow Doppler velocimetry to paint spray: potential and limitations in sizing optically inhomogeneous droplets”, it was found that coffee were used as a paint but in a modern method with the use of water, instant coffee solution and water-based paint with various solid contents. In more recent times, the function of coffee as a dye is more common in the textile industry.

A notable study written by Kyung Hwa Hong (2018) explores the usage of spent coffee grounds in his study of the effects of tannin mordanting on coloring and functionalities of wool fabrics. In this article, the author shares that a large amount of functional materials remain in spent coffee grounds and form discards in the coffee beverage industry. Moreover, the extract from these spent coffee grounds contains sufficient amounts of pigments that can be utilized for textile dyeing. For preparation of the dyed wool fabrics, spent coffee grounds were dried after collecting them from a local coffee house. They were then subjected to extraction using a manual espresso machine. The spent coffee extract was applied to wool fabrics using an infrared (IR) dyeing machine, and after dyeing, the wool fabrics were post-mordanted in various concentrations of aqueous tannin solutions. Zuhri, S., Ilyas, Winanda, M., & Izzaty, N. (2020) elaborated in their study of the “taguchi

method" application to improve the quality of coffee pulp screen printing products that coffee pulp screen printing products are products that are still in research and development, since there are still some problems that arise in the results of coffee pulp screen printing ink. According to the study of Luftinor et al (2020) *Coffee bean skin waste extraction for silk dyeing*, coffee bean waste is a feasible material when it comes to dyeing silk thread especially when the concentration of the coffee bean dye solution, lime solution, and age of the fabric is higher. The color fastness when it comes to washing, sweat, light and rubbing has the same results.

III. RESEARCH PLAN, HYPOTHESIS, AND STRUCTURE

Research Design

Quasi-Experimental is the research design of this study- the feasibility of coffee grounds as an alternative ink. For the researchers to gather adequate data, the researchers would send out a Google Forms questionnaire to the chosen respondents. In addition to the questionnaire, the researchers would utilize the observation method to gather data about the feasibility of KAPINTA. Before the respondents answer the Google Forms questionnaire, the researchers will lend them one (1) prototype of KAPINTA for them to test by using the alternative ink and provided paper. The Google Forms would consist of survey questions in the Likert Scale. The forms aim to gather data about the drying time, ink color, comfortability in writing, viscosity, smear, pigmentation, and cost-effectiveness of KAPINTA. With this, to determine the feasibility of the alternative ink, the researchers would analyze the data from the respondents and the data from the observation of the researchers.

Preparation of Spent Coffee Grounds (SCGs)

The spent coffee grounds (SCGs) will be collected from Starbucks Coffee in Robinsons Place Antipolo who gives away their spent coffee grounds for free. Aside from Starbucks Coffee, the material will also be collected from the researchers' spent brewed coffee grounds.

Criteria of Respondents

For this study, the sample was drawn from the work peers of the researchers. This was done so that the product to be tested would be delivered without obstruction to the respondents amidst the difficulties placed on traveling caused by the Covid-19 pandemic. The researchers focused on the subset of people that fulfilled the following criteria:

a) Those that use ballpens as an everyday tool,

b) Those that are familiar with the different brands of pens sold commercially, and

c) Those that can be easily reached by the researchers.

And so, respondents that were ultimately eligible for the study consisted of colleagues of the researchers that reside in Antipolo City and are currently junior or senior high school students.

Prototype Specifications

Spent coffee grounds (SCGs) and raw honey will be the primary materials in developing the alternative ink. In addition, ethanol and water will be the secondary materials. The researchers would be developing three (3) prototype treatments of KAPINTA. In creating the prototype, only the spent coffee grounds and raw honey will vary in measurement. The ethanol and water will remain constant for the rest of the prototypes.

In addition to the primary materials of the alternative ink, the researchers created a mixture composed of 30 mL of water and 30 mL of ethanol. Then added it to the ink made from spent coffee grounds.

The researchers created three (3) prototypes with different measurements of Spent Coffee Grounds (SCGs) and raw honey. The first treatment consists of 1 cup of Spent Coffee Grounds (SCGs) and 30 mL of raw honey. While for the second treatment consists of 1 ½ cup of Spent Coffee Grounds (SCGs) and 30 mL of raw honey. Furthermore, the third treatment consists of 2 cups of Spent Coffee Grounds (SCGs) and 36 mL of raw honey. The first and second treatments have the exact measurement for raw honey because the researchers thought of only adding the measurement of SCG for the second treatment and maintaining the measurement of raw honey.

Statement of the Problem

The research aims to produce an alternative ink made from spent coffee grounds that helps to decrease the amount of landfill waste. With this, the researchers aims to determine the following:

1. Is the alternative ink more efficient than commercial inks in terms of:
    a. Drying time
    b. Ink color
    c. Comfortability in writing
2. Will the ink made out of spent coffee grounds reach the following standards?
    a. Viscosity
    b. Smear
    c. Pigmentation
    d. Cost-effectiveness
3. Will the materials in different measurements used in creating the ink affect the effectiveness of the product?

Hypothesis

Null Hypothesis (H_0)

1. The alternative ink made out of spent coffee grounds is less efficient than commercial inks in terms of its drying time, permanence, ink color, and comfortability in writing.
2. The alternative ink made out of spent coffee grounds or KAPINTA won’t reach the following standards; the ink will have a low viscosity, smear easily, not-well pigmented, and will not be cost-effective because of its minimal expenditure.
3. The measurement of the materials (spent coffee grounds, honey, ethanol, water) utilized in producing an

alternative ink made out of spent coffee grounds will insignificantly affect the product.

Evaluation Procedure

In determining the feasibility of spent coffee grounds as an alternative ink, the researchers will conduct three trials to test the quality of the alternative ink. For the respondents to easily determine what's the best ink to use, researchers decided to use a table for better representation. The researchers will evaluate the prototype by testing them based on its viscosity, smear, pigmentation, and cost effectiveness. The prototype was compared with a commercially-sold pen with a like-sized nib, meaning both pens yielded the same line thickness of 0.7mm.

1 = Did Not Meet Expectations
2= Fairly Satisfactory
3 = Satisfactory
4 = Very Satisfactory
5 = Outstanding

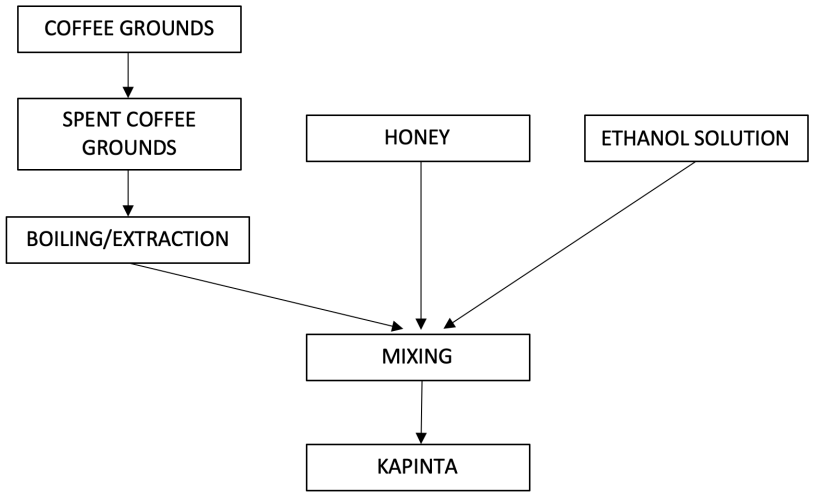
Grading Scale	1	2	3	4	5
Viscosity					
Smear					
Pigmentation					
Cost-effectiveness					

This table will be used to evaluate the three trials of the prototype. After evaluating the three (3) prototypes, the best prototype will be given to the chosen respondents.

Research Locale

The study was conducted at one of the researchers' houses in Antipolo, Rizal, where the feasibility of coffee grounds as an alternative ink was experimented. This significant study has been implemented on the students of LSCA's relatives who are also fellow undergraduates. The research study was implemented outside of LSCA since the school's premises are not yet available for the students' use. Proper area of experimentation and a complete set of tools and equipment was not an issue.

Conceptual Framework



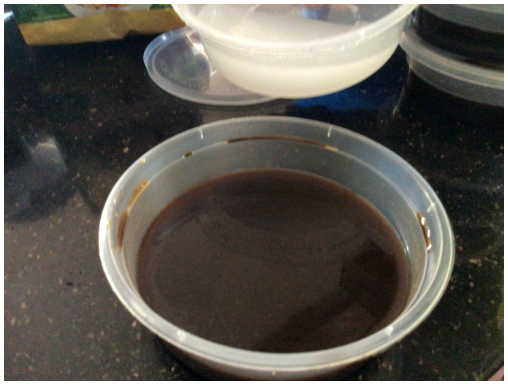
The conceptual framework shows the coffee grounds, honey, and ethanol solution in making the ink. The coffee grounds must be used in order to get the spent coffee grounds. The spent coffee grounds are then to be boiled and extracted. In order for researchers to acquire the ethanol solution, 30 mL of ethanol is mixed with 30 mL of water. After the spent coffee grounds are extracted, it will then be mixed with honey and ethanol solution to produce the Kapinta ink.

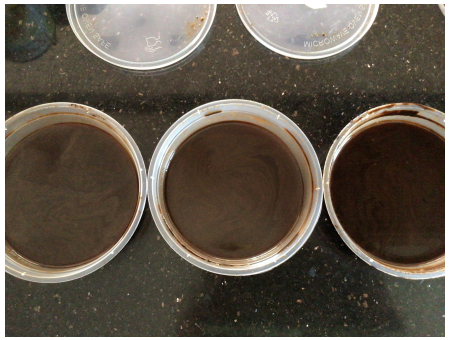
Procedure

To create ink out of spent coffee grounds, you must first prepare the materials, equipment and tools needed. The ingredients are spent coffee grounds, honey, ethanol and water. As for tools and equipment, a pot, strainer, measuring spoons and stove will be utilized.

The first step in developing the prototype is boiling while stirring the spent coffee grounds for 20 minutes. After measuring the water and grounds, add them to a pot and cook at medium heat. This is to extract the dye from the coffee grounds. For this experiment, the spent coffee grounds were collected from Starbucks Coffee Robinsons Place Antipolo. After boiling the spent coffee grounds, the mixture was removed from the heat and set aside to cool. Once the coffee blend reached room temperature, the researchers used a strainer to separate the grounds from the liquid into a bowl. The extracted dye was then strained twice more to ensure that there would be no spent coffee grounds residue left. Next, the researchers whisked the raw honey and ethanol into the extracted dye into the boiled spent coffee grounds. And finally, the ink was left to sit at room temperature overnight to allow for it to settle before filling them into pens.

Documentation





IV. RESULTS AND DISCUSSIONS

Data Presentation

The following table shows the data gathered by the Google Form sent out by the researchers to the research respondents. The researchers sent their prototype of KAPINTA to 13 respondents to test out the prototype and for the researchers to gather data to find out if the spent coffee grounds is a feasible material for developing a sustainable and alternative ink.

Table 4.1 Feasibility of KAPINTA

	Very Poor	**Poor**	**Fair**	**Good**	**Excellent**
Q1	0	0	3	4	6
Q2	0	0	6	2	5
Q3	0	0	3	5	5
Q4	0	1	5	4	3
Q5	0	3	6	2	2

Table 4.1 presents the answers of the respondents regarding the feasibility of KAPINTA. The questions aim to rate the characteristics of KAPINTA in terms of drying time, ink color, comfortability in writing, smoothness, and ink pigmentation.

Table 4.2 Commercial Pens

	Very Poor	**Poor**	**Fair**	**Good**	**Excellent**
Q6	0	0	4	5	4
Q7	0	0	4	3	6
Q8	0	0	6	4	3

Table 4.2 presents the respondents' answers regarding the characteristics of commercial pens provided by the researchers. Similar to Table 4.1 questions, Table 4.2 questions aim to rate the characteristics of the commercial pen in terms of drying time, ink color, and comfortability in writing.

Table 4.3 Comparison between KAPINTA and Commercial Pen

	Strongly Agree	Agree	Neutral	Disgaree	Strongly Disagree
Q9	2	6	4	0	1
Q10	2	5	3	3	0
Q11	2	8	3	0	0
Q12	4	6	2	1	0

Table 4.3 presents the respondents' perception in comparing the prototype provided and the commercial pen. The questions in table 4.3 aim to determine if KAPINTA is more efficient than the commercial pen in terms of drying time, ink color, comfortability in writing and if the respondents view KAPINTA as a feasible alternative ink to commercial pens.

Data Analysis

The data gathered from the Google Forms survey are labeled as ordinal. With this, for the researchers to analyze the gathered data, the researchers utilized the Chi-Square test to test the first and second hypotheses. While for the third hypothesis, the researchers utilized the observation method.

A. First Hypothesis

Table 4.4 Expected and Actual Values in accordance with the first H0

	Expected Values	Actual Values
Strongly Agree	10	10
Agree	10	25
Neutral	10	12
Disagree	11	4
Strongly Disagree	11	1

To comply with the null hypothesis H0: The alternative ink made out of spent coffee grounds is less efficient than commercial inks in terms of its drying time, permanence, ink color, and comfortability in writing, the following expected values were assigned: 10, 10, 10, 11, 11. The numbers under Disagree and Strongly Disagree are 20% + 1 of the total of the observed values(52) and the rest under the Neutral, Agree, and Strongly Agree categories were distributed equally. The researchers set a significant level of α = 5% or 0.05.

Table 4.5 Chi-Square test for first hypothesis

$$X^2 = \sum \frac{(Oi - Ei)^2}{Ei}$$

$= \sum \frac{(10-10)^2}{10} + \frac{(25-10)^2}{10} + \frac{(12-10)^2}{10} + \frac{(4-11)^2}{11} + \frac{(}{}$ $= \sum 0 + 22.5 + 0.4 + 4.45 + 9.09$ $X^2 = 36.44$
Calculating for the degree of freedom: Df = N - 1 = 5 - 1 = 4
$X^2 calculated\ value > X^2 critical\ value$ 36.44 > 9.49

The Chi-Square test yielded a result of 36.44 with 4 degrees of freedom, making the statistic significantly higher than the critical value, 9.49. This drastic difference proves that alternative ink made out of spent coffee grounds is more efficient than commercial inks in terms of its drying time, permanence, ink color, and comfortability in writing. And with that, the null hypothesis is rejected.

B. Second Hypothesis

Table 4.6 Expected and Actual Values in accordance with the second H0

	Expected Values	**Actual Values**
Very Poor	17	0
Poor	17	4
Fair	11	23
Good	10	17
Excellent	10	21

For the null hypothesis H0: the alternative ink made out of spent coffee grounds or KAPINTA will not reach the following standards; the ink will have a low viscosity, smear easily, not well pigmented, and will not be cost-effective because of its minimal expenditure, the expected values are as follow: 10, 10, 6, 6, and 7. (Presented in Table 4.5). 50% + 1 of the expected values are assigned to the Very Poor and Poor category, and the rest is equally distributed to the Fair, Good, and Excellent category. The researchers set a significant level of $\alpha = 5\%$ or 0.05.

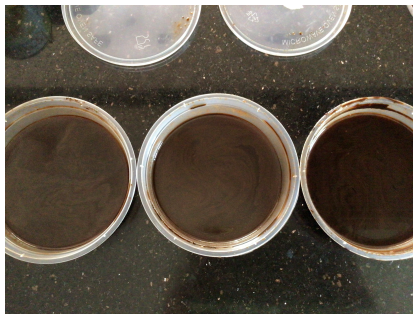
Table 4.7 Chi-Square test for the second hypothesis

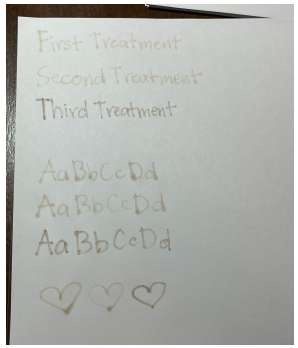
$X^2 = \sum \frac{(Oi - Ei)^2}{Ei}$ = $\sum \frac{(0-17)^2}{17} + \frac{(4-17)^2}{17} + \frac{(23-11)^2}{11} + \frac{(17-10)^2}{10} + \frac{(21-10)^2}{10}$ $= \sum 17 + 9.94 + 13.09 + 4.9 + 12.1$ $X^2 = 57.03$
Calculating for the degree of freedom: Df = N - 1 = 5 - 1 = 4
$X^2 calculated\ value > X^2 critical\ value$ 57.03 > 9.49

With the presented table of the Chi-Square test in accordance with the second hypothesis, the researchers calculated an X^2 = 57.03 with a significance level of α = 5% or 0.05. Since the test statistic (57.03) is greater than the critical value (9.49), the null hypothesis is rejected, and an alternative hypothesis is accepted. Thus, the alternative ink made out of spent coffee grounds or KAPINTA will reach the following standards: the ink will have a high viscosity, will not smear easily, be well-pigmented, and be cost-effective.

C. Third Hypothesis

The study's third statement of the problem seeks to determine if the materials in different measurements used in creating the ink affect the product's effectiveness. With this statement, the hypothesis formulated by the researchers is H0: the measurement of the materials (spent coffee grounds, honey, ethanol, water) utilized in producing an alternative ink made out of spent coffee grounds will insignificantly affect the product. Chapter III of this study states that the researchers developed three prototypes wherein the spent coffee grounds and raw honey will vary in measurement. Other materials used will remain constant.





As seen in the photo, the three (3) treatments differ in color. Based on observation, the third treatment is the darkest and most pigmented among all treatments. While the first and second treatment lacks pigmentation compared to the third treatment. After executing the experiment, the researchers performed the evaluation procedure to observe and decide what

the best prototype they have done is. The first treatment, consisting of 1 cup of SCGs and 30 mL of raw honey is a bit darker than the second treatment. At the same time, the second treatment, which consists of 1 ½ cup of SCG and 30 mL of raw honey, seems to be the lightest among all treatments in terms of pigmentation.

In conclusion, based on the researchers' observation, the prototypes developed seemed to differ from one another. Thus, the null hypothesis H0: the measurement of the materials (spent coffee grounds, honey, ethanol, water) utilized in producing an alternative ink made out of spent coffee grounds will insignificantly affect the product is rejected. The measurement of each prototype significantly affects the prototype itself.

V. CONCLUSIONS AND RECOMMENDATIONS

Conclusion

In accordance with the research results, the following conclusions can be extracted. Firstly, alternative ink made out of spent coffee grounds is more efficient than commercial inks in terms of drying time, permanence, ink color, and writing comfort. This was proved by the resounding agreement in the responses obtained from the survey that insisted that KAPINTA performed better than the conventional ballpen. Next, alternative ink made out of spent coffee grounds has a high viscosity, does not smear easily, is well-pigmented, and is cost-effective. The researchers are confident enough to state this due to the data collected from the respondents. Most people agreed that KAPINTA met these standards based on the resulting statistics.

In addition to all that was already stated, this study has found that a precise measurement of the ingredients used to create alternative ink made out of spent coffee grounds is needed to successfully produce it because the measurement of the materials (spent coffee grounds, honey, ethanol, water) utilized in producing an alternative ink made out of spent coffee grounds significantly affects the product. Not only that, but a strict procedure must also be followed while developing the ink as the handling of ingredients will also affect the result. This is because the pigmentation of the ink varies widely depending on the duration it is boiled for. The more extended spent coffee grounds are boiled, the darker the outcoming ink will be. While conducting the method to create this ink, the researchers had gone through multiple failed attempts before achieving a product that worked as intended. Thus, they have determined that each step, especially those aimed to draw the pigment from spent coffee grounds and measurement of ingredients, plays a crucial role in successfully making the ink.

With all these conclusions from the data analysis, the researchers concluded that coffee grounds are a feasible material for developing a sustainable pen compared to commercial pens. The treatment that consists of 2 cups of Spent Coffee Grounds (SCGs) and 36 mL of raw honey is feasible as an alternative ink.

Recommendations

The first recommendation of the researchers is to test out more quantity of measurements of materials in developing the ink to validate the results of the experiment strongly. Since some characteristics of KAPINTA did not meet the researchers' expectations, testing out different measurements for the treatment may help get the desired effect for the study. The second recommendation of the researchers would also be to test out different variations of spent coffee grounds. In this study, the researchers utilized spent coffee grounds from Starbucks Coffee. As stated in Chapter III, these spent coffee grounds are given for free since the coffee shop has been giving them as coffee grounds for plants. And so, it is important to note that this study does not take into account a specific coffee type. To further expand upon information regarding the different tints of ink as an effect of various choice types of coffee ground, testing out other variations of spent coffee grounds from other coffee shops and even from homebrewed coffee may help develop the color of the ink. The researchers' third recommendation is to have the pen manufactured. The nib and case make up the pen and it may have a significant effect on its pigmentation, drying time, and viscosity. With this process, the product can achieve better results and pigmentations.

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