Mahogany Sawdust Tannin as Ink Source

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Abstract

This study aimed to produce ink from Mahogany sawdust tannin. Specifically, it sought to determine the physical properties of ink using different amounts of glycerol as mordant; the physical properties of ink using different amounts of glycerol in terms of color, odor, and pH; the acceptability of the ink in terms of color, odor, and absorptivity; the best proportion of raw materials in the production of ink; and whether a significant difference exists in the physical properties of the inks in terms of pH. The study used the developmental and descriptive method that involved the production of ink, observation, and testing of the aforementioned properties, as well as a survey of the acceptability of the ink. One-way Analysis of Variance was used to determine whether significant difference exists in the pH of the inks produced using different amounts of glycerol. Findings of the study show that all three sample proportions were black, had a faint pleasant odor, and the pH values were consistent. The ink from Mahogany sawdust tannin was acceptable in terms of color, odor, and absorptivity. The best proportion of the raw materials in the production of ink is 10 milliliters tannin extract, 1 gram ferrous sulfate, 1 gram sodium chloride, 1 milliliter ethyl alcohol, and 3 milliliters glycerol. It has a darker color compared to the other two proportions containing 1 mL and 2 mL of glycerol, respectively. There is no significant difference in pH among the three ink samples containing different amounts of glycerol. The ink produced from Mahogany sawdust has been found very highly acceptable.

Keywords: Mahogany, sawdust, tannin, mordant, glycerol, absorptivity

Bio-note:

Mary Jonie Oricio Villanueva is a Registered Chemist, earned a Master's Degree in Chemistry from the University of St. La Salle and a Ph.D. in Technology Management, which she completed at Carlos Hilado Memorial State College in Talisay City, Negros Occidental. She currently serves as faculty at the College of Education, Arts, and Sciences of STI West Negros University in Bacolod City. Her research interest lies in using indigenous materials in innovating cost-effective and environment-friendly products.

Introduction

Stakeholders in the academe do engage in activities that use ink in almost every situation. These activities range from sending out instructions to receiving communications, writing assignments to reproducing test materials, and much more related activities. Technology has evolved, and this valuable classroom commodity can be found practically in felt-tip flair pens, TUL retractable gel pens, uniball signo gel pens, pilot G2 retractable gel pens, amazon basics felt-tip marker pens, metallic marker pens, maped visio left-handed pens, and BIC gel-ocity quick drying pens, among others. In any school-related activity, the use of ink found on pens now being sold in the market seems so indispensable especially for teachers and students alike.

Tannins, which are used in this study, serve as colorants in the production of ink. They are pale yellow to light brown and produce a dark color when mixed with iron salts. Correspondingly, this study has two goals: to produce writing ink; and to manage solid waste produced by mahogany sawdust. Specifically, this study aimed to produce ink from Mahogany sawdust tannin. The study further explored its acceptability among users in terms of color, odor, and absorptivity. The best proportion of raw materials to produce an acceptable ink was likewise explored.

The Tannin Content of Mahogany Sawdust

From Wiley's online library (1994), tannin was found to be present in wood dust (sawdust). The tannin concentration of hard- and soft-wood dust was determined in dust powder and in samples on filters. It varied from 1.6 ± 0.3 mg/g ($\pm$ SD) for fir, which is a soft wood, to 80 ± 30 mg/g ($\pm$ SD) for oak, which is a hard wood. In five woodworking shops where samples were taken, the concentrations of the total dust varied from 0.2 to 20 mg/m^3, while those of tannins varied from 2 to 341 $\mu g/m^3$. Hard woods like oak or mahogany have a higher tannin concentration than soft woods.

Shorea negrosensis Locally as Lumber and Source of Tannin

To indicate that we have sufficient source of sawdust, and hence tannin, from the local lumber mills and woodworking industries as the target of this study, Region 6 is ranked the third log-producing region and Negros Occidental is ranked number 6 among the top 10 log-producing provinces in the Philippines with a production of 18,976 cubic meters per year. Of this volume, 1,435 cubic meters is *Shorea negrosensis* (www.wood-databasecom).

Background on Tannin

Tannins are also called tannic acid. They are a group of pale yellow or light brown amorphous substance in the form of powder, flakes, or a spongy mass and they are widely distributed in plants. The chief uses of tannin are tanning leather, dyeing fabric, making ink, and in various medical applications. Tannins occur in the roots, wood, bark, leaves, and fruit of many plants, particularly in the bark of oak species and in sumac and myrobalan, and also in good quantity among the group of trees that we know as mahogany.

Materials and Methods

This paper used the developmental and descriptive method of research. It involved the production, observation and testing of the properties of ink from tannin obtained from Mahogany sawdust. It also included a survey of the acceptability of the ink. The acceptability of the product was determined through a valid and reliable survey instrument. The product was tested for acceptability through evaluation of ink samples in the three different proportions of glycerol for faculty members, students, and artists to test by writing, drawing, or doodling on paper. Their observations were taken on the acceptability of the ink.

The following score cards were used to determine the acceptability of the ink in terms of color, odor, and absorpitivity. (Color: 5= Excellent; 4=Very satisfactory; 3=Satisfactory; 2=Unsatisfactory; and 1= Poor; Odor: 5=Very good odor; 4=Good odor; 3=Acceptable odor; 2=Slightly malodorous; and 1=Repulsive; Absorptivity on each of the three criteria: 5= Excellent; 4=Very satisfactory; 3=Satisfactory; 2=Unsatisfactory; and 1= Poor).

Materials and Tools

The different raw materials, tools, and equipment used are listed hereunder. The materials were the consumables and the tools which consist of the glassware and metallic wares commonly found in the laboratory.

Table 1
List of Materials Used

Materials	Use/Purpose	Quantity	Unit
Distilled water	Solvent in the extraction of tannin from sawdust	6	L
$FeSO_4$	Reacts with tannin to give it black color	30	g
Glycerol	Mordant--gives the ink more viscosity	60	mL
Ethyl alcohol	Preservative and improves the odor	60	mL
NaCl	Preservative, anti-bacteria	60	g
Bond paper	To write samples of ink on	100	pcs

Distilled water was used to extract tannin from the sawdust. In order to have sufficient allowance for evaporation of water heated during the extraction process and to provide sufficient quantity of the three samples offered to the respondents for testing, 6 liters was more than enough. Likewise, the quantities of the other materials used, as shown above, provided enough allowance.

The different tools and equipment in the chemistry laboratory and their corresponding uses or purposes for this experiment is listed hereunder.

Table 2
List of Tools and Equipment Used

Tools and Equipment	Use/Purpose
Beakers, 100 mL	Vessel for mixing ink Ingredients
Beaker, 1000 mL	Vessel for boiling sawdust in extraction of tannin
Bunsen burner	For heating
Graduated cylinder, 50 mL	For measuring volume of tannin extract
Graduated cylinder, 10 mL	For measuring volume of ethyl alcohol and glycerol
Cheese cloth	Filter to separate boiled sawdust from (liquid) tannin solution
Stirring rod	For stirring solutions
Tripod	Holds 1000-mL beaker and wire gauze over Bunsen burner flame
Water bath	Provides steam for controlled heating (maintained at or below 65°C)
Wire gauze	Supports 1000-mL beaker on the tripod over the flame
Laboratory thermometer	For monitoring the temperature
Mortar and pestle	Grinding Mahogany charcoal into powder
Spatula	Scraping and spooning solid matter
Disposable plastic gloves	Protection of hands from harmful substances and stains
Digital balance	Precision weighing
Digital pH meter	For determination of acidity of the ink
Lightweight box	Keeping the sample bottles
Small glass bottles	Storing the sample products

Table 3
Bill of Materials

Cost of Materials				
Quantity	Unit	Material and Description	Unit Cost	Total Cost
1	bottle	Distilled water, 6-L bottle	72.50/bottle	72.50
1	m	Cheesecloth, 1 meter length	50.00/m length	50.00
60	mL	Ethyl alcohol, 99% concentration	100.00/L	6.00
60	mL	Glycerol, pure	12.50/30mL	25.00
10	g	$FeSO_4$, pure	600.00/500 g	12.00
60	g	NaCl, ordinary grade table salt	15.00/kg	0.90
100	pcs	Bond paper, substance 20	1.00/pc	100.00
1000	g	Mahogany sawdust	FREE	FREE
			Total	366.40

Distilled water was obtained from supermarkets. Cheesecloth was obtained from a good textile store downtown. Ethyl alcohol of 99% concentration was obtained from certain chemical supply companies, as the local drugstores have such substance in only 70% concentration. Glycerol was obtained from chemical supply companies and large drug stores. Table salt was obtained at a public market. Substance 20 bond paper, of which the quantity prepared for this study was more than sufficient to allow for wastage, was obtained from school and office supply stores. Mahogany sawdust was obtained from small-scale sawmills and furniture shops near STI WNU.

Process Flow in Making the Ink

Mahogany sawdust (100 g) was placed into a 1000-mL beaker. Distilled water (500 mL) was added. Before heating the mixture of distilled water and *Shorea negrosensis* sawdust, it was allowed to stand overnight. The following day, the mixture was heated on a water bath for 3 hours. The mixture was stirred every 15 minutes while maintaining the temperature between 60°C to 65°C. The Bunsen burner was removed from the set-up (or turned off) every time the temperature reached 60°C. The heat of the water vapor from the water bath increased the temperature of the mixture even after the burner had been removed. Hence, the necessity of removing (or turning off) the burner from the set-up before the maximum allowable temperature was reached.

During the extraction process, the color of the liquid phase slowly darkened. The change in color ranged from light yellow to reddish-brown. After heating for the required time, the mixture was filtered using cheesecloth. The filtrate, which is the tannin extract, was collected in another beaker. The presence of tannin in the extract was confirmed by performing qualitative tests. The beaker containing the tannin extract was placed on a water bath. Heat was applied to a maximum temperature of 65°C. Most of the water content of the tannin extract was evaporated until a solution more viscous than the first was obtained.

Meanwhile, the following procedures outline the qualitative tests conducted to ascertain that what was extracted was really tannin. Five trials (replicates) were made in each test.

Physical Examination

The extracted liquid was subjected to physical examination, namely for color, odor, and taste. The results of these tests are shown in Table 5.

Reaction with Litmus Paper

Litmus is used for testing whether a substance is acid or base. Acid, or an acidic substance, turns blue litmus to red and causes red litmus to remain red. Base, or a basic substance, turns red litmus to blue and causes blue litmus to remain blue. The results of this test are shown in Table 6 below.

Precipitation of Gelatin, Starch, and Albumin

Tannin causes precipitates to form in gelatin, in starch, and in albumin. The results of this test are shown in Table 7 below.

Reaction with Ferric Chloride and Ferrous Sulfate

The color of tannin changes when certain iron compounds are added to it. This phenomenon is the basis upon which this paper, to produce ink from tannin, is founded. The results of this test are shown in Table 8 below.

Reduction of Fehling's Solution and Benedict's Reagent

Both Fehling's solution and Benedict's reagent cause a reduction reaction that gives precipitates `a characteristic red color on tannin. The results of these tests are shown in Table 9 below.

Preparation of the Ink from the Tannin Extract

After the extracted solution had been verified to be tannin extract, the main procedure for producing ink from the tannin extract began.

In a 100-mL beaker, 10 mL of the concentrated tannin extract was placed. 1 mL glycerol, 1 g NaCl, 1 g $FeSO_4$, and 1 mL ethyl alcohol, were added to 10 mL tannin extract. The mixture was stirred until it was completely combined and dissolved. This constituted Sample 1. Although the color of ink produced was black, the color changed to brown (sepia) once it dried on paper. This is because the natural color of Mahogany is reddish brown. 99% ethyl alcohol was used to improve the odor of the ink and at the same time served as an additional preservative.

Two more mixtures were made using the same procedure, using 10 mL tannin extract, 1 g $FeSO_4$, 1 g NaCl, 1 mL ethyl alcohol, and 2 mL glycerol for Sample 2; and using 10 mL tannin extract, 1 g $FeSO_4$, 1 g NaCl, 1 mL ethyl alcohol, and 3 mL glycerol for Sample 3. These three samples were kept in separate glass bottles to be offered to the respondents for evaluation. Table 4 summarizes the constitution of the three different samples of ink.

Table 4
Preparation of Ink

Sample	Tannin Extraxt	Glycerol	NaCl	$FeSO_4$	Ethyl alcohol
1	10 mL	1 mL	1 g	1 g	1 mL
2	10 mL	2 mL	1 g	1 g	1 mL
3	10 mL	3 mL	1 g	1 g	1 mL

Qualitative Tests for the Ink

After the ink was produced, the 3 different samples qualitative tests, namely test for color and test for odor. For each sample, the color of the ink was observed to be black and the odor was pleasant. The results of these observations are shown in Table 5.

Determination of pH

To measure the acidity (pH) of the ink, a digital pH meter was used. A pH number less than 7 indicates an acidic substance, a pH of 7 indicates neutral (7 is the pH of pure water), and a pH number more than 7 indicates a basic (alkaline) substance. The results of testing the three ink samples for pH are shown in Table 10.

The ink was stored in glass jars with a lid and kept in separate boxes in a cool dark location. Many natural inks are not lightfast and will lose color and brilliance if stored in a sunny location. Also, it was necessary to use glass bottles as there might be contamination reactions if the ink were stored in containers of other materials, as glass does not react with almost any kind of substance.

Data Gathering Procedure

Property Testing

The three different inks produced using different amounts of glycerol were compared as to color, odor, and absorptivity. The color, odor, and absorptivity had been evaluated by the respondents using the Likert's scale of 1 to 5.

Color. This was evaluated by the respondents in the acceptability test using the Likert's scale of 1 to 5, with 1 being of poor color and 5 being of excellent color.

Odor. This was evaluated by the respondents in the study, whether the odor was offensive or not, before and after the ink was applied to paper, using the Likert's scale of 1 to 5, with 1 being of offensive odor and 5 being of a pleasing odor.

Absorptivity Test

The three different ink samples offered were used to write on one side only of separate clean sheets of bond paper. Then three different tests were asked of the respondents: (a) the time it took for each ink sample to dry; (b) whether the ink marks on the obverse side of the page smudged when the paper was handled; and (c) whether the ink bled through the page to be visible on the reverse side. For the evaluation factors to be used by the respondents, the results were observed carefully for clarity of stroke, retention of original color, and leftover "halos" or ink bleeding around the markings on the obverse. The judging factors determined the score or rating for each kind of ink with 5 as the highest, indicating the ink's retention on the paper, and 1 as the lowest.

Statistical Analysis

To facilitate the analysis and interpretation of the results associated with the different properties tested in the production of ink from tannin, a one-way Analysis of Variance (ANOVA) was used as the statistical tool. One-way ANOVA at 5% level of significance was used to determine if there was any significant difference in the pH of the three ink samples. This tool is appropriate because the researcher compared ink in three proportions: that which had 1 mL, 2 mL, and 3 mL of glycerol, respectively. This type of research involved single group design, a univariate analysis because only one variable was used in each of the three different proportions. Correspondingly, the mean was used to determine the validity of the Ink Quality Evaluation instrument as well as its acceptability.

Results and Discussion

Qualitative Tests for the Tannin Extract

The tables that following show the results of the qualitative tests to verify whether the extracted liquid was really tannin. Table 5 presents the results of the physical examination of the liquid extracted from heating Mahogany sawdust in distilled water.

Table 5
Results of the Physical Examination of the Extracted Liquid

REPLICATE	COLOR
1	Reddish-brown
2	Reddish-brown
3	Reddish-brown
4	Reddish-brown
5	Reddish-brown

The reddish brown color of the extract is one of the characteristics of tannin, which has a slight woody odor and an astringent taste. These physical characteristics were demonstrated by the tannin extract. Table 6 shows the reaction of litmus paper to the liquid that was extracted. An acidic solution turns litmus to red; an alkali (or basic) solution turns litmus to blue.

Table 6
Reaction with Litmus Paper

REPLICATE	BLUE LITMUS	RED LITMUS
1	Turned bluish-red	Remained red
2	Turned bluish-red	Remained red
3	Turned bluish-red	Remained red
4	Turned bluish-red	Remained red
5	Turned bluish-red	Remained red

The blue litmus paper did not completely turn red when a drop of the tannin extract was added to it. It simply turned bluish-red, indicating only slight acidity. This reaction demonstrates one of the properties of tannins. When the process was repeated using a red litmus paper instead of blue, no change in color was observed. The red litmus paper remained red. This shows that the tannic extract is acidic. Table 7 shows the color of the precipitates when gelatin, starch, and albumin were added to, respectively, three separate test tubes of the extracted liquid.

Table 7
Precipitation of Gelatin, Starch, and Albumin

REPLICATE	1% GELATIN SOLUTION	1%STARCH SOLUTION	1% ALBUMIN SOLUTION
1	White precipitate	White precipitate	Brown precipitate
2	White precipitate	White precipitate	Brown precipitate
3	White precipitate	White precipitate	Brown precipitate
4	White precipitate	White precipitate	Brown precipitate
5	White precipitate	White precipitate	Brown precipitate

Gelatin, starch, and albumin solutions formed precipitates with the tannin extract with the colors enumerated in the table. This positive result confirms the presence of tannin in the extract. Table 8 shows how the extracted solution reacts with two iron reagents. In fact, mixing tannin with either of these iron compounds is historically how black ink was made.

Table 8
Reaction with $FeCl_3$ and $FeSO_4$

REPLICATE	FERRIC CHLORIDE ($FeCl_3$)	FERROUS SULFATE ($FeSO_4$)
1	Green-black precipitate	Green-black precipitate
2	Green-black precipitate	Green-black precipitate
3	Green-black precipitate	Green-black precipitate
4	Green-black precipitate	Green-black precipitate
5	Green-black precipitate	Green-black precipitate

The green-black precipitate formed with $FeCl_3$ and $FeSO_4$ is another proof that tannin is present in the extract. Another thing indicated by the color of the precipitate is the group with which the tannin in the extract belongs. A blue-black color is a positive test for pyrogallol tannins while a green-black color is for the catechol groups. Since the color of the precipitate is green-black, the tannin that has been extracted from Mahogany belongs to the catechol group. The final tests conducted on the extract were the reduction of Fehling’s Solution and Benedict’s Reagent, the results of which are shown in Table 9.

Table 9
Reduction of Fehling's Solution and Benedict's Reagent

REPLICATE	FEHLING'S SOLUTION	BENEDICT'S REAGENT
1	Brick red precipitate	Brick red precipitate
2	Brick red precipitate	Brick red precipitate
3	Brick red precipitate	Brick red precipitate
4	Brick red precipitate	Brick red precipitate
5	Brick red precipitate	Brick red precipitate

Reduction of Fehling's solution, as indicated by the brick red precipitate formed, confirms the presence of the reducing property in the extract. Benedict's reagent was also reduced by the tannin extract. This reaction was indicated by the formation of a brick red precipitate. This is another confirmation of the presence of the reducing property in the extract.

Physical Properties of Ink Using Different Amounts of Glycerol

The first objective of the study was to determine the physical properties of ink using different amounts of glycerol in terms of color and pH. Table 10 shows the results of the qualitative tests conducted to determine the color, odor, and pH of the ink produced.

Table 10
Qualitative Tests for Ink

	Color Sample			pH Sample		
Replicate	1	2	3	1	2	3
1	Black	Black	Black	1.08	1.10	1.08
2	Black	Black	Black	1.08	1.08	1.08
3	Black	Black	Black	1.09	1.07	1.09
4	Black	Black	Black	1.08	1.09	1.08
5	Black	Black	Black	1.07	1.08	1.08

In these qualitative tests, the color was visually noted to be black with just the slightest tinge of brown. With regards to odor, it was faint and just barely perceptible. The slight odor that can be sensed was pleasant, not offensive. In the test for acidity on the three ink samples, the pH was consistent. The ink samples were acidic. It was desirable that the ink must be acidic for optimum absorption on paper.

Acceptability of the Ink

The second objective of the study was to determine the acceptability of the ink among the respondents surveyed. Table 11 presents the tabulation of the means computed from the Acceptability Survey.

Table 11
Results of the Acceptability Survey

	Sample 1	Verbal Interpretation	Sample 2	Verbal Interpretation	Sample 3	Verbal Interpretation
Color	4.22	Very Satisfactory	4.00	Very Satisfactory	4.35	Very Satisfactory
Odor	3.925	Satisfactory	4.00	Very Satisfactory	4.45	Very Satisfactory
Absorptivity	4.39	Very Satisfactory	4.31	Very Satisfactory	4.35	Very Satisfactory
Average Mean	**4.18**	**Very Satisfactory**	**4.10**	**Very Satisfactory**	**4.38**	**Very Satisfactory**

In terms of color and odor, Sample 3 had the highest mean of 4.35 and 4.45, respectively, which means that it was very highly acceptable. On the other hand, Sample 1 had the highest mean of 4.39, interpreted as very highly acceptable, for absorptivity. However, as a whole, Sample 3 obtained the highest average mean of 4.38, which makes it very highly acceptable among the three samples presented to the respondents.

Best Proportion of Raw Materials

The third objective of the study was to determine the best proportion of raw materials used in the production of the ink. Based on the result of the Acceptability Survey, the best proportion for the ink is 10 mL tannin extract, 1 g $FeSO_4$, 1 g NaCl, 1 mL ethyl alcohol, and 3 mL glycerol.

Difference in the Physical Properties of Ink in Terms of pH

The fourth objective of the study was to determine whether significant difference exists in the physical properties in terms of pH. In order to determine the difference in the physical properties of the different samples of ink in terms of pH, analysis of variance was used as the instrument. The following Tables 12 and 13 show the results of ANOVA.

Table 12
Data on Tests of pH

					95% Confidence Interval for Mean			
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Sample 1	5	1.0800	0.00707	0.00316	1.0712	1.0888	1.07	1.09
Sample 2	5	1.0840	0.01140	0.00510	1.0698	1.0982	1.07	1.10
Sample 3	5	1.0820	0.00447	0.00200	1.0764	1.0876	1.08	1.09
Total	15	1.0820	0.00775	0.00200	1.0777	1.0863	1.07	1.10

Table 13
ANOVA Table on Difference in pH Level

pH	Sum of Squares	df	Mean Square	F	Verbal Interpretation
Between Groups	0.000	2	0.000	0.300	No Significant Difference
Within Groups	0.001	12	0.000		
Total	0.001	14			

The results displayed in Tables 12 and 13 showed that the computed F-value of 0.3, which is lower than 3.88 at 0.05 level of significance, indicates no significant difference among the pH of the different ink samples. Hence, the null hypothesis which states that there is no significant difference in the pH among the ink produced using different amounts of glycerol is hereby accepted.

Subsequent analyses of the results obtained through the different procedures of property testing that were conducted revealed the following findings: 1) Although the color of ink produced was black when seen during the mixing process, the color changed to brown once it dried on paper. This is because the natural color of Mahogany is reddish brown. 2) When the amount of glycerol in the ink was varied, there was no detectable difference in color and odor, nor was there any significant difference in the pH as shown by the readings of the digital pH meter. 3) The ink is very highly acceptable in terms of color, odor, and absorptivity to users.

This paper found that the best proportion of the raw materials in the production of ink is 10 milliliters tannin extract, 1-gram ferrous sulfate, 1-gram sodium chloride, 1 milliliter ethyl alcohol, and 3 milliliters glycerol. As a final point, this paper found no significant difference in the pH among the inks produced when different amounts of glycerol were used. This further implies that the absorptivity was not affected by the change in the amount of glycerol.

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Nonetheless, it was also apparent that the resulting ink had such thin consistency that it is not good for use on felt-tip markers. Further research might dwell on the possibility of using other binders like gum Arabic, using sawdust obtained from other trees, and producing colored ink would all prove beneficial to stakeholders earlier mentioned.

The origin of tannins, their historical evolution, their different types, and their applications are described by Pizzi (2019). Accordingly, old and established applications are described, as well as the future applications which are being developed at present and that promise to have an industrial impact in the future. The chemistry of some of these applications is discussed where it is essential to understand the tannins and their derivatives' role. The essential points of each application, their drawbacks, and their chance of industrial application are briefly discussed (Pizzi, 2019).

Conclusion

This paper aimed to explore the viability of producing ink from Mahogany sawdust tannin, which was obtained from sawmills and furniture shops in the vicinity of STI West Negros University in Bacolod City. Since other sawmills used wood from the same species of Mahogany, it was deemed that sawdust obtained from these sources was representative of sawdust available from other similar sources. Other raw materials like ferrous sulfate, sodium chloride, and ethyl alcohol were kept constant during the formulation of the different samples of ink that were later subjected to analyses. Findings reveal that the production of ink from the same source is possible and that the product has been found to be user-friendly in terms of color, odor, and pH especially if prepared with the best proportion of raw materials. Further analysis showed that varying the amount of glycerol found no effect on the color, odor, or pH of the inks produced, and that adding 3 mL glycerol while keeping all of the other ingredients constant produced the best proportion of ink from Mahogany sawdust. Further research might dwell on the possibility of using other binders like gum Arabic, using sawdust obtained from other trees, and producing colored ink would all prove beneficial to stakeholders earlier mentioned. Finally, it was also apparent that the resulting ink had such thin consistency (viscosity) that it is not good for use on felt-tip markers.

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