Effectiveness of Organic Alternatives as Acid-Base Indicators in the School's Science Laboratories

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INTRODUCTION

The letters pH stands for power of hydrogen and used to measure how acidic and basic a solution is. This measurement is important in science education such as chemistry, biology, medicine, food and environmental science, oceanography, civil engineering and many other fields.

According to Lumen Learning (n.d.), in the field of science education, pH or acid-base indicators are frequently employed in titrations in analytical and organic chemistry, even in biology to determine the extent of a chemical reaction. For this reason, different types of indicators are used to measure the pH of solutions.

Most of the commonly used pH indicators are commercial indicators, which are made synthetically such as phenolphthalein, methyl red and methyl orange. Also, acid-base indicators like litmus papers and pH strips are considered to be synthetic. These commercial pH indicators are usually of high cost. Thus, leads to unavailability or limited quantity in the science laboratories (Alijandre and Ripalde, 2015).

Aside from high cost, synthetic commercial pH indicators are said to be made up of compounds that are highly polluting, harmful and hazardous for the environment (Chemistry Stack Exchange, n.d).

Since the world has become aware for environmental issues, various researches are being undertaken extensively by many scientists all over the world in this field for production of natural products that will serve as pH indicators in which it will be less hazardous, lower cost, easily available, and eco-friendly.

Dalubhasaan ng Lunsod ng San Pablo, as a local college, sometimes lacks funding for equipment and supplies most especially in science laboratories due to resources like chemicals and indicators that are needed are too expensive and considerably not affordable.

Statement of the Problem

The study aims to test the effectiveness of organic alternatives as acid-base indicators in the school's science laboratories. The study sought to answer the following:

1. What are the changes in color that happens to the organic extracts during pH indication application?

2. Is there a significant relationship to the use of alternative organic pH indicators in science laboratories in terms of:

a. Cost effectiveness

b. Safety and Hazards

c. Availability of materials

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3. Is there any significant relationship between the results in the application of the alternative organic pH indicators and phenolphthalein (synthetic) pH indicator to different acid and base solutions?

Research Hypothesis

1. There is no significant relationship between the use of alternative organic pH indicators in science laboratories to cost effectiveness, safety and hazard and availability of materials.

2. There is no significant relationship between the results in the application of the alternative organic pH indicators and phenolphthalein (synthetic) pH indicator to different acid and base solutions

Conceptual Paradigm

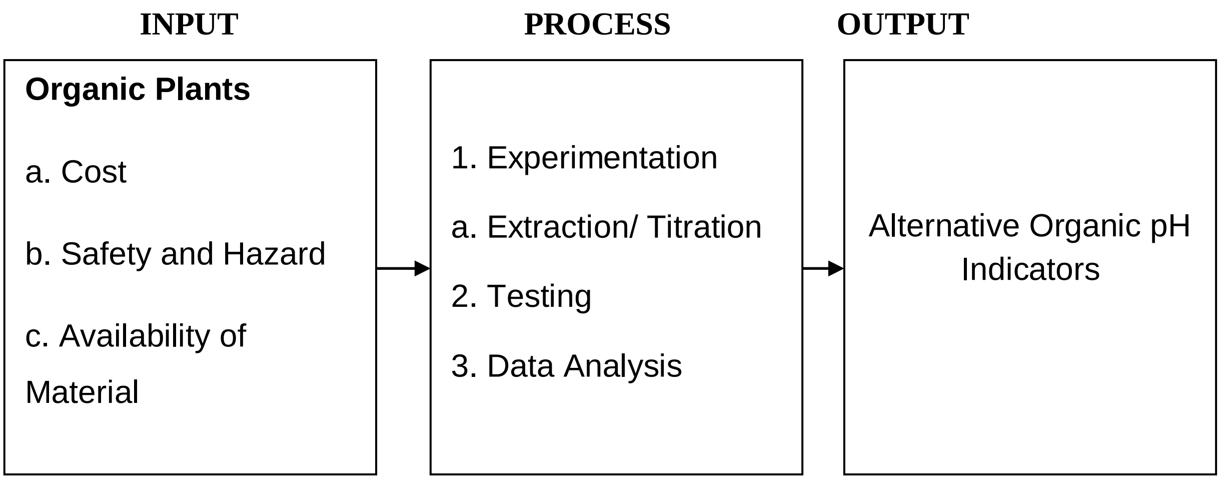

Figure 1.1 Shows the diagram of input, process and output where the study will focus on having the product alternative organic pH indicator made from abundant plants in the environment which will undergo the process of experimentation.

Conceptual Framework

About 1300, Arnaldus de Villa Nova who is a Spanish scholar, began to use litmus for studying acids and bases. He extracted a dye from lichen and was the first known scholar to use it as a test of acidity. The idea was then expanded by the known scientist Robert Boyle who found that certain plant derived substances changes color in the presence of acids or bases. One example was syrup of violets, which is blue in a pH neutral environment but turns green when exposed to bases, and red when mixed with acid.

The use of natural dyes as acid–base indicators were first reported in Boyle's collection of essays, Experimental History of Colours. Boyle made an important contribution to the early theory of acids and bases by using indicators for the classification of these substances. However, this idea may actually have originated much earlier by medieval painters who used natural dyes treated with vinegar and limewater to make different color watercolor paints (Alijandre and Ripalde, 2015).

Since then acid and base titrations were made from organic extracts but eventually replaced by synthetic chemicals as time goes by and technologically advancing era.

Titration is the basic chemistry laboratory technique for the quantitative analysis of substances with unknown concentrations using standard solutions of known concentration. The substance with unknown concentration and the standard solution are termed analyte and titrant respectively (Pradeep & Kapil, 2013).

Synthetic chemicals which are used as internal indicators in acid base titrations that are being hazardous can be substituted by using the natural indicators which gives results with the same accuracy. Natural indicators are proven to be easy to prepare and are easily available.

Significance of the Study

This study is potential in addressing the effectiveness of organic extracts as alternative acid and base indicators in the science laboratories. This research study could provide researchers the development and modification of titrations using alternative acid and base indicators most especially researchers in the field of science education. In addition, the results of the study can be used as a basis to find possible solutions to the existing problems in terms of availability of materials/ resources in science laboratories of state universities and colleges.

This study would be beneficial to the following:

Students. They will be able to use the organic extract as an effective and safe substitute to those expensive commercial indicators in measuring the pH of a solution.

To the institution. They can introduce the organic extract in their science laboratories as an effective substitute to the frequently use commercial indicators such as phenolphthalein, provided that these extract sourced from sweet potato tops is less expensive and safe to use.

To the community. The study will give great value to the common organic plant (sweet potato tops). Thus, the study will give the needed interest to the people of the community to become motivated in cultivating the plant.

Scope and Limitation of the Study

This study will focus only in determining the significant effect of the organic extracts as an alternative acid and base indicator to be used in the science laboratories testing different types of chemical solutions.

Students will be involved during the data gathering of this study which are Bachelor in Secondary Education Major in Science students of the Department of Teacher Education, Dalubhasaan ng Lunsod ng San Pablo. The study will be conducted also as a part of laboratory activity on the topic acid and base titrations on their major subject analytical and organic chemistry, second semester, (midterm) A.Y. 2019-2020. Data gathering will only be done inside the chemistry laboratory of the school.

Conceptual Literature

Organic Plants

According to (Sharma, et. al., 2013) there are various plants which show good acid base indicator activity against various synthetic ph indicators as follows: Antirrhinum majus (Scrophularaceae), Bombax malabaricum (Malvaceae), Butea monosperma (Fabaceae), Calendula officinalis (Compositae), Careya arborea (Lecythidaceae), Dahlia pinnata (Asteraceae), Helianthus annus (Asteraceae), Hibiscus rosa sinensis (Malvaceae), Ipomoea biloba (Convolvulaceae), Ixora coccinea (Rubiaceae), Jacaranda acutifolia (Bignoniaceae), Morus alba (Moraceae), Phyllanthus reticulates (Euphorbiaceae) and Punica granatum (Punicaceae). These plants are strongly recommended that its dye and extract can be used as alternative to various synthetic pH indicators during titrimetric analysis as an indicator in all types of acid base titrations because of its economy, simplicity and wild availability.

As stated by Helmenstine, Ph.D. (2019), there are many common household products and garden plants that can be used as pH indicators. Most plants encompass pH-sensitive anthocyanins, making them perfect for testing acid and base levels. Many of these natural pH indicators exhibit a broad range of colors. The natural world has given us numerous plants, from beets to grapes to onions, which can be used to test the pH levels of

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a solution. These natural pH indicators include beets, blackberries, blueberries, cherries, curry powder, delphinium petals, geranium petals, grapes, horse chestnut leaves, morning glories, onion, petunia petals, poison primrose, purple peonies, red (purple) cabbage, rose petals and turmeric. Additionally, she also stated some common household chemicals to test pH levels. These include baking soda, color-changing lipstick, ex-Lax tablets, vanilla extracts and washing soda.

Similarly, Helmenstine, Ph.D. (2019) analyzed that many fruits and vegetables contain pigments that change color in response to pH, making them natural and edible pH indicators. Most of these pigments are anthocyanins, which commonly range in color from red to purple to blue in plants, depending on their pH. As well as plants containing anthocyanins include acai, currant, chokeberry, eggplant, orange, blackberry, raspberry, blueberry, cherry, grapes, and colored corn. Specifically, any of these plants may be used as pH indicators. To change the colors of these plants, the process that can be done with the need to increase their acidity or alkalinity.

Acid and Base Properties

The theory of acids and bases are defined as acid (often represented by the general formula HA) is generally a chemical compound that when dissolved in water will produce a solution with a pH less than 7. As he contested, in the modern definition, an acid is a substance that can give a proton (H + ions) to other substances (called bases), or may receive a free electron pair of the bases. An acid reacts with a base in a neutralization reaction to form a salt. Acids have a sour taste and are corrosive or damaging the metal. Furthermore, the general definitions of the bases are chemical compounds that release hydroxide ions (OH -) when dissolved in water. Base is the opposite of acid, which is intended to elements / compounds that have a pH more than 7. Bases have a bitter taste and are caustic and feel slippery. In chemistry and cooking, many substances dissolve in water to make it either acidic or basic/alkaline. A basic solution has a pH greater than 7, while an acidic solution has a pH of less than 7. Aqueous solutions with a pH of 7 are considered to be neutral. Acid-base indicators are substances used to determine roughly where a solution falls on the pH scale.

A particular type of acid-base indicator is a universal indicator, which is a mixture of multiple indicators that gradually changes color over a wide pH range. The indicators are chosen so mixing a few drops with a solution will produce a color that can be accompanied with an approximate pH value. In table 1.1 it shows several plants and household chemicals can be used as pH indicators, but in a lab setting, these are the most common chemicals used as indicators:

Table 1.1 Table of Common pH Indicators

Indicator	Acid Color	Base Color	pH Range	pK_{In}
thymol blue (first change)	red	yellow	1.2 - 2.8	1.5
methyl orange	red	yellow	3.2 - 4.4	3.7
bromocresol green	yellow	blue	3.8 - 5.4	4.7
methyl red	yellow	red	4.8 - 6.0	5.1
bromothymol blue	yellow	blue	6.0 - 7.6	7.0
phenol red	yellow	red	6.8- 8.4	7.9
thymol blue (second change)	yellow	blue	8.0 - 9.6	8.9
phenolphthalein	colorless	magenta	8.2 -10.0	9.4

The "acid" and "base" colors are relative. Also, he noted some popular indicators display more than one color change as the weak acid or weak base dissociates more than once.

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Titration

Kapilraj et.al. (2019), titration is the most common laboratory method of quantitative chemical analysis that is used to determine the concentration of analyte. The most of the modern laboratories are fortified with digital automatic titrators that are facilitated with sensors (pH sensor/voltage electrode), some of them do not require indicators, the results of accuracy are high and human errors also reduced than conventional titration methods. However, the kinetic factors concerns the chemical reaction and the response of the indicating system are of paramount importance. Cell configuration, stirring, and positioning of the end-point detector and of input of the titrant are to be considered for ensuring high accuracy. Piston burettes and peristaltic pumps are commonly being used as devices for automatic transfer of titrant in automatic titrators. The piston burettes are highly reliable, but are expensive while the peristaltic pumps are highly versatile, but require frequent calibration due to the continual changes in the physical properties of the flexible tubes employed and has a relatively short lifetime [1]. Cost of the automatic titrators together with the drawbacks concerned as the major hurdles for the usage of automatic titrators in many of the developing countries in the world and thereby conventional titrimetric methods are still extensive used by the analytical and research laboratories in these countries.

Clark (2013) indicated that Phenolphthalein is another commonly used indicator for titrations, and is another weak acid.

$$\text{H-phph}_{(aq)} \rightleftharpoons \text{H}^{+}_{(aq)} + \text{phph}^{-}_{(aq)}$$

Figure 1

In this case, the weak acid is colourless and its ion is bright pink. Adding extra hydrogen ions shifts the position of equilibrium to the left, and turns the indicator colourless. Consequently, adding hydroxide ions removes the hydrogen ions from the equilibrium which tips to the right to replace them - turning the indicator pink. The half-way stage happens at pH 9.3. Since a mixture of pink and colourless is simply a paler pink, this is difficult to detect with any accuracy.

Keerthanan (2019) stated that commonly used indicators for acid-base titrations are synthetic, and this work was focused to identify the eco-friendly natural indicators and to determine their pKa values. The analytical potential of the flower extracts is very promising as seen in its application in acid-base titrimetry. The selected flower extracts were found to perform well in titrating strong acid-strong base than in weak acid-strong base. They have obtained a sharp and clear colour change from red to brownish yellow for the *Bougainvillea glabra* extract, from red to yellow for the *Bauhinia purpurea* extract, and from red to brownish yellow for the *Impatiens balsamina* extract. All the three flower extracts gave clear colour change with acids and bases, and the colour change was maintained with different acids and bases. The sharp contrast between their colours in acid and base made the pigment suitable for use as acid-base indicators. As those flower extracts have very simple, cost-effective, environment friendly extraction procedure and excellent performance with sharp colour change in end points of the titrations, it would be possible to replace the standard indicators being used in conventional laboratories with natural flower indicators.

Cost-Effectiveness Acceptability Curves

Cost-effectiveness acceptability curves (CEAC) is defined as it can provide a graphical representation of the decision uncertainty associated with an intervention. They also present the probability that the decision to adopt an intervention is correct (i.e., that the intervention is cost-effective compared with the alternatives given the current evidence) for a range of values of the cost-effectiveness threshold (λ). This probability is essentially a Bayesian definition of probability (i.e., the probability that the hypothesis is true given the data), although some commentators have given the CEAC a Frequentist interpretation.

Availability of Materials

The general definition of availability is the characteristic of a resource that is committable, operable, or usable upon demand to perform its designated or required function. It is the collection of the resource's accessibility, reliability, maintainability, serviceability, and securability. While, the quality control: Ability of an item to perform its designated function, whenever required.

Safety and Hazards

The meaning of the word hazard can be perplexing. Often dictionaries do not give exact definitions or combine it with the term "risk". For example, one dictionary defines hazard as "a danger or risk" which helps clarify why many people use the terms interchangeably.

There are many definitions for hazard but the most frequent definition when talking about workplace health and safety is:

A hazard is any cause of potential damage, harm or adverse health effects on something or someone.

Fundamentally, a hazard is the probable for harm or an adverse effect (for example, to people as health effects, to organizations as property or equipment losses, or to the environment).

Related Studies

In the study conducted by Lavanya, et. al. (2018), the extract from Nerium indicum, rosa centifolia, ixora coccenia flower was tested for its use as an acid-base indicator and the results were compared with what obtained using phenolphthalein for strong acid-strong base (HCl and NaOH), strong acid-weak base (HCl and NaHCO3), weak acid-strong base (CH3COOH and NaOH) titrations. The equivalence point of the titrations using flower extract is almost close or coincides with that of synthetic indicators for all the titrations.

Also, Lavanya, et. al., (2018) emphasized that the synthetic indicators like phenolphthalein, methyl orange and phenol red are not only hazardous to health but are also prominent pollutants. Based on their study it is evident that the use of natural indicators in the acid base titrations is statistically proved. The natural indicator prepared from Nerium indicum, Rosa centifolia, Ixora coccinea flower petal is neither harmful to the environment nor it causes any health hazard.

Another study Mahadi and Abubakar (2012), reveals that the potentials of flower extracts as indicator and confirmed the assertion that; nearly all brightly colored flowers (six plants namely; Flamboyant (delonix regia), Bougainvillea (bougainvillea globra), Oleander, Pumpkin and Chinese rose (hibiscusrose senensis), and Dutchman’s pipe (aristolochiaceae durior) can be used as indicators. The titration was conducted with three drops of the extracts showed a colours change at each equivalent –point (end-point). The endpoint colours were the same (colourless) for each extract (as the colours changed in acid) and the average titre values obtained matched with the commercial (standard) phenolphthalein indicator was compared. The findings therefore, indicate an alternative way of equipping laboratory with practical instructional material (indicator) using plants that are around or within the environment.

Meanwhile, in a different study wherein Moringa oleifera flower extract was tested, it is proven effectively be used as indicator for acid-base titration, as it is an equally substitute methyl orange and phenolphthalein. In most of the readings obtained by (Khalid, et.al., 2016), the difference between the mean values was ±0.3. Similarly, standard deviations for the titration’s values were obtained as ±0.025 these testifies the potentiality of the extract and were found to be within the expected and permissible statistical range of their study.

In addition, Chipkar (2016) analyzed the eco-friendly natural acid-base indicator properties of four flowering plants from western ghats which have undergone method of four different types of acid-base titrations such as strong acid against the strong base, strong acid against a weak base, weak acid against the strong base and weak acid against weak base that were carried out in the study. As for the results in his study, the titration values were very close with an equivalence point obtained by standard indicator phenolphthalein. Therefore, his work proved to be acceptable in introducing natural pigments as a substitute to the synthetic acid-base indicators.

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RESEARCH DESIGN AND METHODOLOGY

This chapter focuses on the procedure and techniques to be used in the study. It includes the research design, respondents of the study, research instrument, data gathering procedure, and the statistical treatment of data.

Research Design

The study will utilize descriptive experimental method as research design. The experimental method of research is a procedure involving experimental manipulation of conditions and to study the relative effects of various treatments applied to a sample by measuring what was tested (Mitchell, 2015).

In this case the effectiveness of the alterative organic pH indicator will be tested comparing to effectiveness of Phenolphthalein as an acid-base indicator.

Sampling Techniques

Respondents for the study will be selected through the cluster sampling technique. In a clustered sample, subgroups of the population are used as the sampling unit known as clusters, rather than individuals. There are two subgroups to be used in the study. The first subgroup is composed of ten teachers who are handling science laboratory subjects mainly focusing on biology and chemistry, while the second subgroup is composed of incoming second- and third-year science major students.

Research Locale

Respondents are from the institution, Dalubhasaan ng Lunsod ng San Pablo at Brgy. San Jose, San Pablo City, Laguna. They will be matched according to the course and field of their specialization, science subject, as they are taking up and associated to. Furthermore, they are the ones to benefit on the future results of the study.

Experimentation will be conducted inside the biology and chemistry laboratories at Academic Building 3.

Research Instruments

The main instruments for the gathering data and are needed to answer the research problem in the study were self-made survey questionnaires. A 10-item survey questionnaire for the student respondents wherein it is composed of the questions regarding the comparison of the effectiveness of organic pH indicator and phenolphthalein, while there will be 25-item survey questionnaires for science teachers composing of questions associated also to the comparison of the effectiveness of organic pH indicator and phenolphthalein and with the properties of organic plants in terms of its cost effectiveness, safety and hazard, and availability of material.

To improve objectivity, pH meters were used alongside visual observations. Standard buffer solutions (pH 4.0, 7.0, 10.0) were used for calibration.

Validation of Research Instrument

The instruments will undergo internal and external validation. Validators will be some of the researchers' colleagues. Some of them are the subject coordinator for science and the director of the research department. Suggestions and recommendations to be made by the Research Council to improve the researchers' instruments including the questionnaires will be taken in immediate response by the researcher after the validation.

Data Gathering Procedure

In the beginning of the study, experimentation will be done inside the science laboratory to conduct the extraction/ titration of the organic pH indicator which are the camote tops. The students will be instructed to do the following procedure:

1. In a 250 mL beaker, put 200 mL water and 15 pcs of camote tops (leaves slightly washed to remove soil or excess particles)
2. Boil for about 10-15 minutes using the tripod, wire gauze and alcohol lamp as the source of heat, until you see dark green extract
3. Separate the extract and camote leaves using a funnel and filter paper. Let it cool for 2-3 minutes.
4. Soak strips of paper into the organic extract and let it dry.

Finished product will then be tested to certain acid/base solutions like common household products (detergent, vinegar) and other chemicals. Changes in color of the acid-base indicator Phenolphthalein will also be done. This process will be shown and presented to the respondents.

Three batches of camote top extract were prepared to test reproducibility. Each batch underwent titration and endpoint pH was recorded using a calibrated pH meter.

Specifically, google forms survey questionnaires will be administered to the respondents after conducting the experimentation and testing process.

Statistical Treatment of Data

Descriptive and inferential statistics were applied. Independent sample t-tests were conducted to compare indicator effectiveness. Pearson correlation was used to assess consistency between batches.

For the qualitative data, mean scores will be gathered from the result of survey questionnaires and will be interpreted regarding the changes in color of the organic pH indicator.

For the quantitative data, correlation analysis will be used. Correlation is a bivariate analysis that measures the strength of association between two variables and the direction of the relationship. In terms of the strength of relationship, the value of the correlation coefficient varies between +1 and -1. A value of ± 1 indicates a perfect degree of association between the two variables. In this case the result of organic pH indicator and result of phenolphthalein will be compared and correlated (Statistics Solutions, n.d.)

The compare means t-test is used to compare the mean of a variable in one group to the mean of the same variable in one, or more, other groups. The null hypothesis for the difference between the groups in the population is set to zero. We test this hypothesis using sample data. (Nijs, 2019)

RESULTS AND DISCUSSION

This chapter provides findings on relevant result and discussion about the effectiveness of the alternative organic acid-base indicator based on the research instruments used in the study.

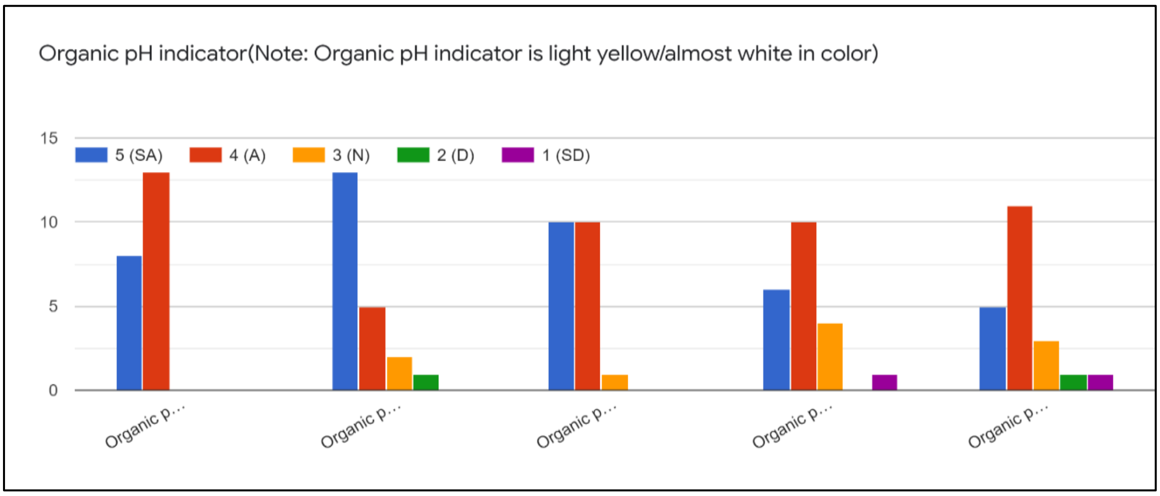

Figure 1. Chart Summary of the conducted survey as to effectiveness of the organic acid-base indicator

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Mean Values	Verbal Interpretation (in terms of effectiveness, cost effectiveness)
0.1 - 1	Not effective at all (NE)
1.01 - 2	Slightly effective (SE)
2.01 - 3	Moderately effective (ME)
3.01 - 4	Very effective (VE)
4.01 - 5	Extremely effective (EE)

Table 1. Effectiveness of Organic Acid Base Indicator

	Frequency						
	5 (SA)	4 (A)	3 (N)	2 (D)	1 (SD)	MEAN	Verbal Interpretation (VI)
a. Organic pH indicator changes color when it reacts with a weak acid.	8	13	0	0	0	4.38	EE
b. Organic pH indicator changes color when it reacts with a strong acid. (light yellow to neon pink)	12	5	2	1	0	4.43	EE
c. Organic pH indicator do not change in color when it reacts with a neutral solution. (light yellow only)	10	10	1	0	0	4.43	EE
d. Organic pH indicator changes color when it reacts with a weak base. (light yellow to green)	6	10	4	1	0	4.0	VE
e. Organic pH indicator changes color when it reacts with a strong base. (light yellow to neon green)	5	11	3	1	1	3.86	VE

The table shows the mean values perceived from the 21 student respondents as to the effectiveness of the organic acid-base indicator. There is a mean value of 4.38 pertaining that organic acid-base indicator changes color when it reacts with a weak acid, verbally interpreted as extremely effective. 4.43 mean value pertains to both criterion that the indicator changes color when it reacts with a strong acid (light yellow to neon pink) and indicator do not change in color when it reacts with a neutral solution (light yellow only), interpreted as extremely effective. In addition, there is a mean value of 4.00 as to extremely effective, when the indicator changes color when it reacts with a weak base (light yellow to green). While there is 3.86 mean value in this interpreted as very effective when indicator changes color when it reacts with a strong base (light yellow to neon green).

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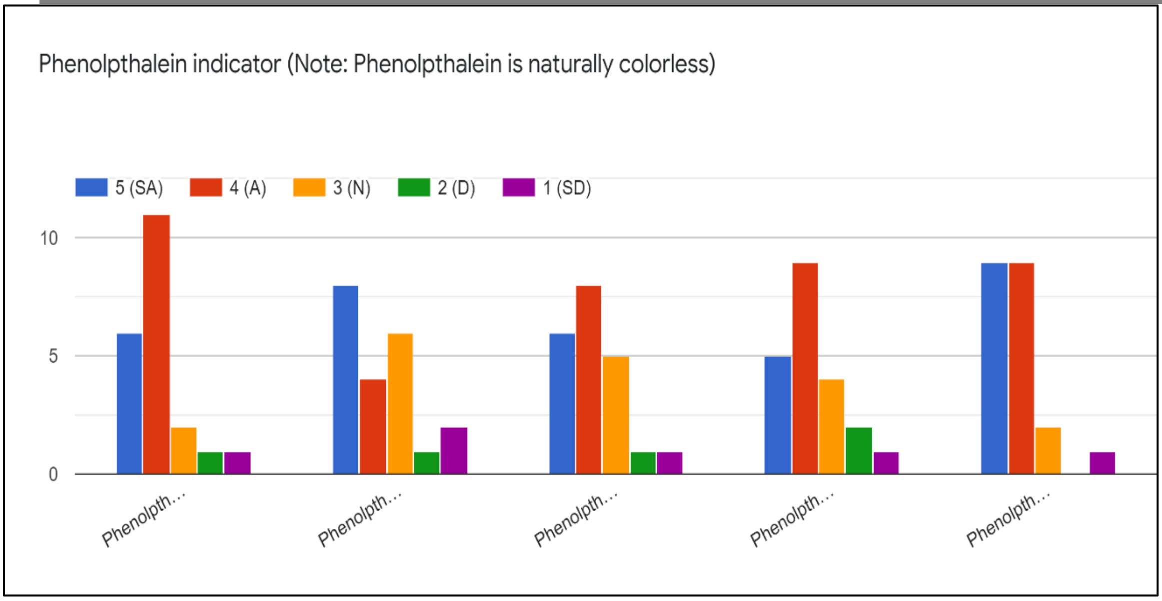

Figure 2. Chart Summary of the conducted survey as to effectiveness of the phenolphthalein acid-base indicator

Table 2. Effectiveness of Phenolphthalein Acid-Base Indicator

	Frequency						
	5 (SA)	4 (A)	3 (N)	2 (D)	1 (SD)	MEAN	VI
a. Phenolphthalein pH indicator do not change color when it reacts with a weak acid. (remains colorless)	6	11	2	1	1	3.95	VE
b. Phenolphthalein pH indicator do not change color when it reacts with a strong acid. (remains colorless)	8	4	6	1	2	3.71	VE
c. Phenolphthalein pH indicator do not change in color when it reacts with a neutral solution. (remains colorless)	6	8	5	1	1	3.81	VE
d. Phenolphthalein pH indicator change in color when it reacts with a weak base. (colorless to light pink)	5	9	4	2	1	3.71	VE
e. Phenolphthalein pH indicator change in color when it reacts with a strong base. (colorless to dark pink)	9	9	2	0	1	4.19	EE

The table shows the mean values perceived from the 21 student respondents as to the effectiveness of the phenolphthalein as an acid-base indicator. As to the four criterion such as phenolphthalein do not change color when it reacts to a weak acid, strong acid, neutral solution and change color when it reacts to a weak base, it has mean values of 3.95, 3.71, 3.81 and 3.71 respectively, all perceived as very effective. While the last criterion in which the phenolphthalein indicator change in color when it reacts with a strong base. (colorless to dark pink) has a mean value of 4.19, considered as extremely effective.

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Table 3. Comparison on the mean rating of organic acid-base indicator and commercial acid-base indicator

Mean Values	Verbal Interpretation (in terms of effectiveness, cost effectiveness)
0.1 - 1	Not effective at all (NE)
1.01 - 2	Slightly effective (SE)
2.01 - 3	Moderately effective (ME)
3.01 - 4	Very effective (VE)
4.01 - 5	Extremely effective (EE)

	Organic Acid-Base Indicator	Phenolphthalein
Indicator reacts/changes color to weak acid	4.38	3.95
Indicator reacts/changes color to strong acid	4.43	3.71
Indicator do not react/change color to neutral solutions	4.43	3.81
Indicator reacts/changes color to weak base	4.0	3.71
Indicator reacts/changes color to strong base	3.86	4.19

The table shows the comparison between the mean values in terms of effectivity of the Organic alternative acid-base indicator and phenolphthalein.

In terms of its reaction to a weak acid and strong acid, phenolphthalein has 3.95 and 3.71 mean values, which are less than 4.38 and 4.43 mean values respectively of the organic acid-base indicator. It reveals that the organic acid-base indicator is more reactive and effective than phenolphthalein when it reacts with acids, considering that phenolphthalein's color remains unchanged when it reacts to acids.

While in reaction to neutral solutions, phenolphthalein has a mean value of 3.81 less than 4.43 mean value of organic acid-base indicator. This also reveals that organic acid-base indicator is more reactive and effective than phenolphthalein.

As for the reactions in basic solutions of the two indicators being compared, phenolphthalein when it reacts to a weak base, it has a mean value of 3.71 less than organic acid-base indicator, which has a mean value of 4.00 indicating it, is less effective than the latter. Meanwhile, in terms of the reaction of the indicators to strong bases, organic acid-base indicator has a mean value of 3.86 less than 4.19 mean value of phenolphthalein. This shows that commercial phenolphthalein is more reactive than the organic-acid base indicator.

As the two indicators were compared in terms of its effectivity, there is a close count of their mean values, interpreted that are both considered very effective.

These results are supported by the study conducted by Lavanya, et. al. (2018) in which she stated that the equivalence points of the titrations using flower extract (organic extracts which has similar characteristics to this study) is almost close or coincides with that of synthetic indicators for all the titrations.

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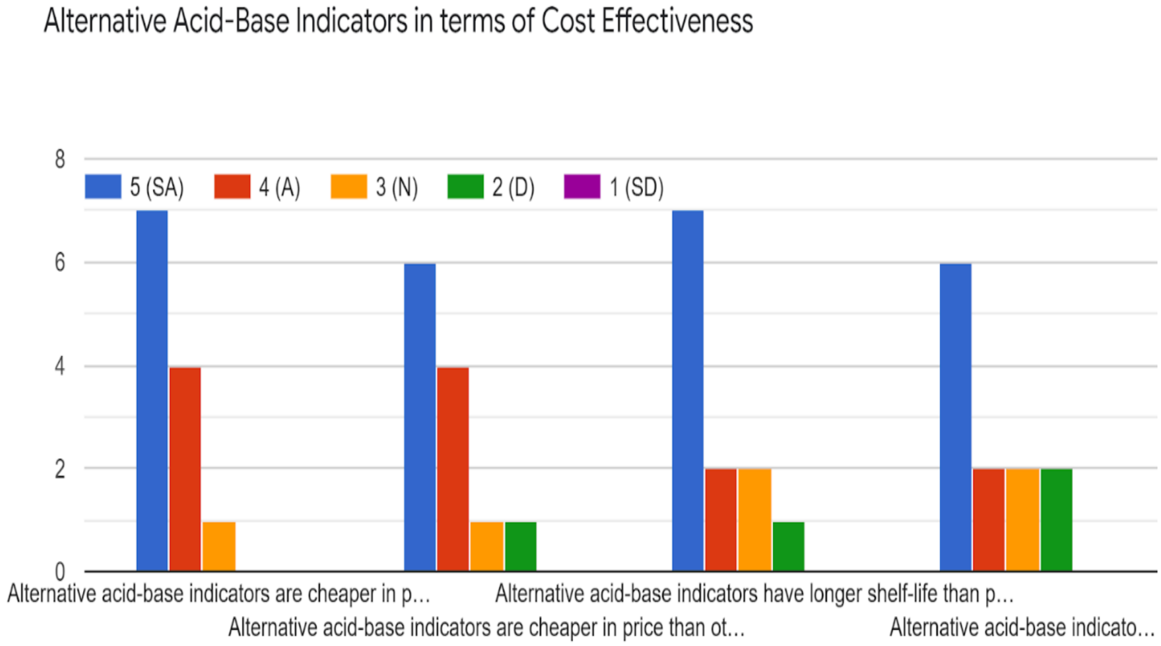

Figure 3. Chart Summary of the conducted survey as to cost-effectiveness of the organic acid-base indicator

Table 4. Alternative Acid-Base Indicator as to its Cost effectiveness

	Frequency						
	5 (SA)	4 (A)	3 (N)	2 (D)	1 (SD)	MEAN	VA
a. Alternative acid-base indicators are cheaper in price than phenolphthalein	8	6	1	0	0	4.47	EE
b. Alternative acid-base indicators are cheaper in price than other commercial litmus papers	7	6	1	1	0	4.27	EE
c. Alternative acid-base indicators have longer shelf-life than phenolphthalein which is more reactive in sensitive environments	8	3	3	1	0	4.20	EE
d. Alternative acid-base indicators have longer shelf-life than commercial litmus papers which is more reactive in sensitive environments	6	4	3	2	0	3.93	VE

The table shows the result of the mean values of the organic acid-base indicator in terms of its cost effectiveness. As to the four criterion of having cheaper price than commercial phenolphthalein, litmus papers, and having longer shelf-life than phenolphthalein, litmus papers resulting to infrequent purchases it shows mean values of 4.47, 4.27, 4.20, and 3.93 respectively. Pertaining to extremely cost-effectiveness and very cost-effective.

Supporting this data**,** during the experimentation process, phenolphthalein costs Php 237.00 for 15 ml that can only be used for 30 trials/times, comparing to Php 11.00 worth of ingredients to make 200 strips of organic acid-base indicators that can be used for 200 times.

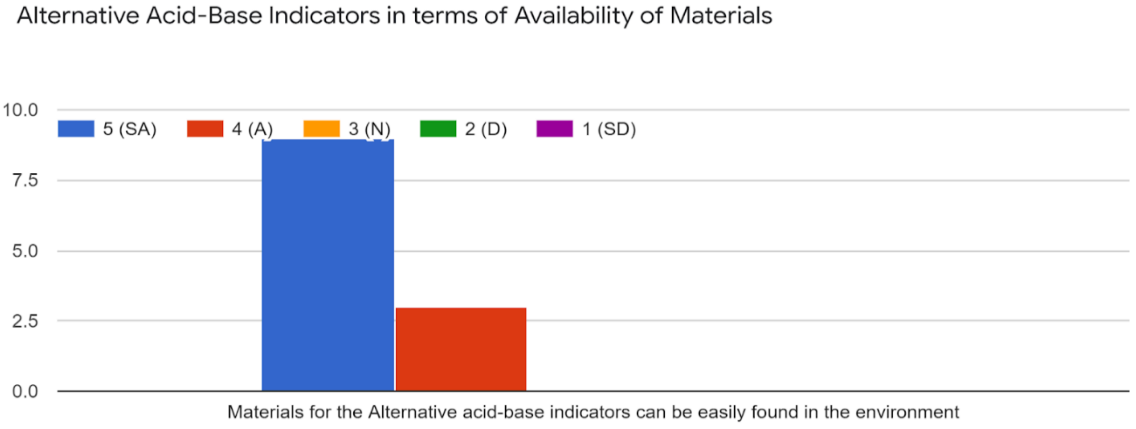

Figure 4. Chart Summary of the conducted survey as to Availability of Materials for the organic acid-base indicator

Mean Score	Verbal Interpretation
0.1 - 1	Not available at all (NA)
1.01 - 2	Slightly available (SA)
2.01 - 3	Moderately available (MA)
3.01 - 4	Available/Abundant (A)
4.01 - 5	Extremely available/abundant (EA)

Table 5. Alternative Acid-Base Indicator in terms of Availability of Materials

	Frequency						
	5 (SA)	4 (A)	3 (N)	2 (D)	1 (SD)	MEAN	VA
a. Materials for the Alternative acid-base indicators can be easily found in the environment	10	4	1	0	0	4.60	EA

The table shows the mean value of the organic acid-base indicator in terms of availability of materials. It is reflected that there is a mean value of 4.60 which is verbally interpreted as extremely available/ abundant. It is perceived that the materials for creating the organic acid-base indicator can be easily found in the environment.

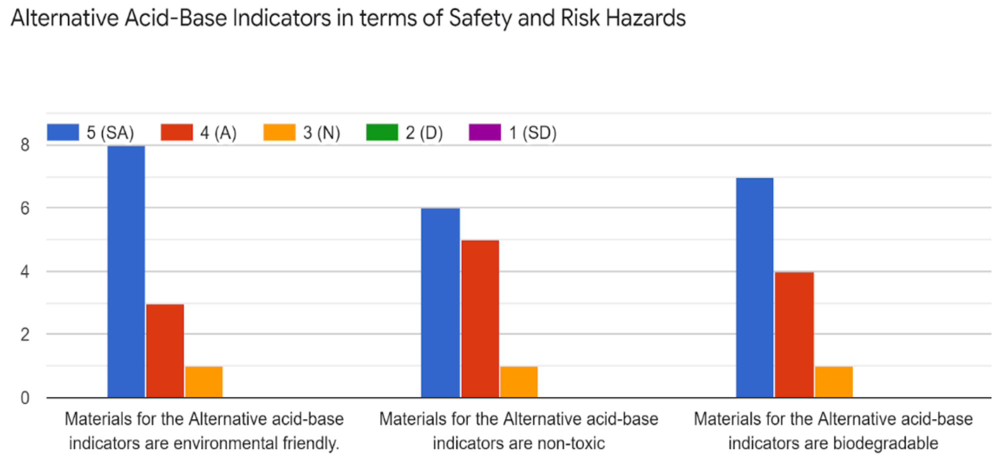

Figure 5. Chart Summary of the conducted survey as to Safety and Risk hazards the organic acid-base indicator

Mean Score	**Verbal Interpretation**
0.1 - 1	Not safe at all (NS)
1.01 - 2	Slightly safe (SS)
2.01 - 3	Moderately safe (MS)
3.01 - 4	Safe (S)
4.01 - 5	Extremely safe (EA)

Table 6. Alternative Acid-Base Indicators in terms of Safety and Risk Hazards

	Frequency						
	5 (SA)	4 (A)	3 (N)	2 (D)	1 (SD)	MEAN	VA
a. Materials for the Alternative acid-base indicators are environmental friendly.	10	4	1	0	0	4.60	ES
b. Materials for the Alternative acid-base indicators are non-toxic	8	5	2	0	0	4.40	ES
c. Materials for the Alternative acid-base indicators are biodegradable	9	5	1	0	0	4.53	ES

The table shows the mean values of organic acid-base indicators in terms of Safety and Risk Hazards. It is seen that in the three criterion for safety and hazard such as being environmental friendly, non-toxic and biodegradable, organic acid-base indicator resulted to 4.60, 4.40 and 4.53 which is interpreted as extremely safe from risks and hazards.

It can be supported by the claim of Lavanya, et. al., (2018) in her study regarding organic acid-base indicators that natural indicator prepared from Nerium indicum, Rosa centifolia, Ixora coccinea flower petal is neither harmful to the environment nor it causes any health hazard. Opposite to the use of synthetic indicators like phenolphthalein, methyl orange and phenol red which are not only hazardous to health but are also prominent pollutants

SUMMARY, CONCLUSIONS, RECOMMENDATIONS

This chapter presents a summary of findings, conclusions, and recommendations based on the data analyzed in the previous chapter.

Summary

The focus of this study was to determine the effectiveness of organic alternative acid-base indicator, most specifically sweet potato (camote) tops at Dalubhasaan ng Lunsod ng San Pablo's science laboratory.

The research approach used in this study was experimental. The respondents were a class of twenty-one (21) students who were taking teacher education programs major in science and fifteen (15) science instructors for a total of thirty-six (36) respondents. Each student respondent were asked to create their own organic acid-base indicator in the laboratory and answered the survey questionnaires guided by the science instructors.

The study utilized post-laboratory questionnaires that was administered to students after they were done through the experimentation process.

Summary of Findings

The following reveals the findings of this research.

1. The mean values of the organic acid-base indicator in terms of effectiveness compared to phenolphthalein showed a relative far greater value. Mean values resulted to the range of 3.86 and above verbally interpreted as very effective to extremely effective.
2. The mean values of the organic acid-base indicator in terms of cost- effectiveness showed a high value. Mean values resulted to the range of 3.93 and above verbally interpreted as very cost-effective to extremely cost- effective.
3. The mean value of the organic acid-base indicator in terms of availability of materials also showed a high value. Mean value resulted to 4.60 verbally interpreted as extremely available/abundant materials.
4. The mean values of the organic acid-base indicator in terms of safety and risk hazards showed a high value. Mean values resulted to the range of 4.40 and above verbally interpreted as extremely safe to risks and hazards.

Conclusions

Based on the findings the following conclusions were drawn:

There is a statistically significant difference ($p < 0.05$) between organic and synthetic indicators' performance in acid-base reactions. The organic indicators demonstrated consistent results across batches, confirmed with pH calibration.

There is a significant difference between the results in the application of the alternative organic pH indicators and phenolphthalein (synthetic) pH indicator to different acid and base solutions, therefore, null hypothesis is not sustained.

There is a significant relationship between the use of alternative organic pH indicators in science laboratories to cost effectiveness, safety and hazard and availability of materials, therefore, null hypothesis is not sustained.

Recommendations

Based on the results and conclusions of the study, the following recommendations are hereby suggested:

1. Since the study revealed that there is a significant difference between the results in the application of the alternative organic pH indicators and phenolphthalein (synthetic) pH indicator to different acid and base solutions, it is recommended that organic acid-base indicator be an alternative acid-base indicator in science laboratories.
2. Since the study revealed that there is a significant relationship between the use of alternative organic pH indicators in science laboratories to cost effectiveness, safety and hazard and availability of materials, it is recommended to use organic acid-base indicator in science laboratories, in order to save expenses, materials and avoid laboratory hazards.
3. A similar study may be conducted but not limited to only one organic ingredient as an alternative. The researchers may add self-made questionnaires for students' perceptions and suggestions that may be considered as additional data.
4. Researchers are encouraged to adopt organic indicators validated with instrumental pH data. Future work should explore more organic sources, use broader samples, and conduct long-term stability tests.

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APPENDICES

Research Instrument/ Questionnaires

Survey Questionnaire of Effectiveness of Organic Alternatives as Acid-base Indicators in the School's Science Laboratories

INSTRUCTION: Put a checkmark on the appropriate rating for the following criteria. You may write comments/suggestions in the separate box provided.
The following is the list of ratings and their equivalent meaning.

5- Strongly Agree (SA)
4- Agree (A)
3- Neutral (N)
2- Disagree (D)
1- Strongly Disagree (SD)

*Required

Organic pH indicator(Note: Organic pH indicator is light yellow/almost white in color) *

	5 (SA)	4 (A)	3 (N)	2 (D)	1 (SD)
Organic pH indicator changes color when it reacts with a weak acid. (light yellow to pink)	○	○	○	○	○
Organic pH indicator changes color when it reacts with a strong acid. (light yellow to neon pink)	○	○	○	○	○
Organic pH indicator do not change in color when it reacts with a neutral solution. (light yellow only)	○	○	○	○	○
Organic pH indicator changes color when it reacts with a weak base. (light yellow to green)	○	○	○	○	○
Organic pH indicator changes color when it reacts with a strong base. (light yellow to neon green)	○	○	○	○	○

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Phenolpthalein indicator (Note: Phenolpthalein is naturally colorless) *

	5 (SA)	4 (A)	3 (N)	2 (D)	1 (SD)
Phenolpthalein pH indicator do not change color when it reacts with a weak acid. (remains colorless)	○	○	○	○	○
Phenolpthalein pH indicator do not change color when it reacts with a strong acid. (remains colorless)	○	○	○	○	○
Phenolpthalein pH indicator do not change in color when it reacts with a neutral solution. (remains colorless)	○	○	○	○	○
Phenolpthalein pH indicator change in color when it reacts with a weak base. (colorless to light pink)	○	○	○	○	○
Phenolpthalein pH indicator change in color when it reacts with a strong base. (colorless to dark pink)	○	○	○	○	○

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Experimentation Procedures

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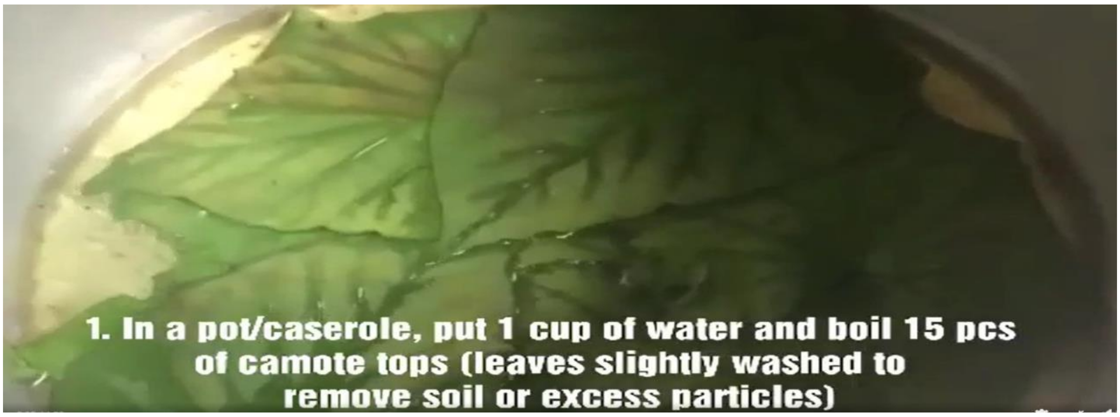

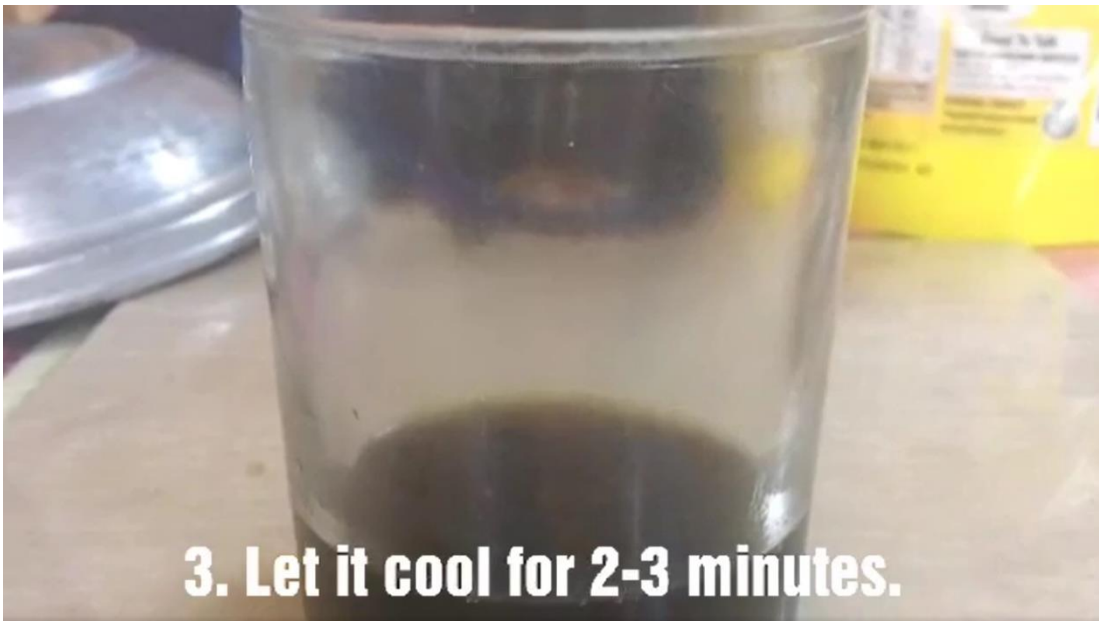

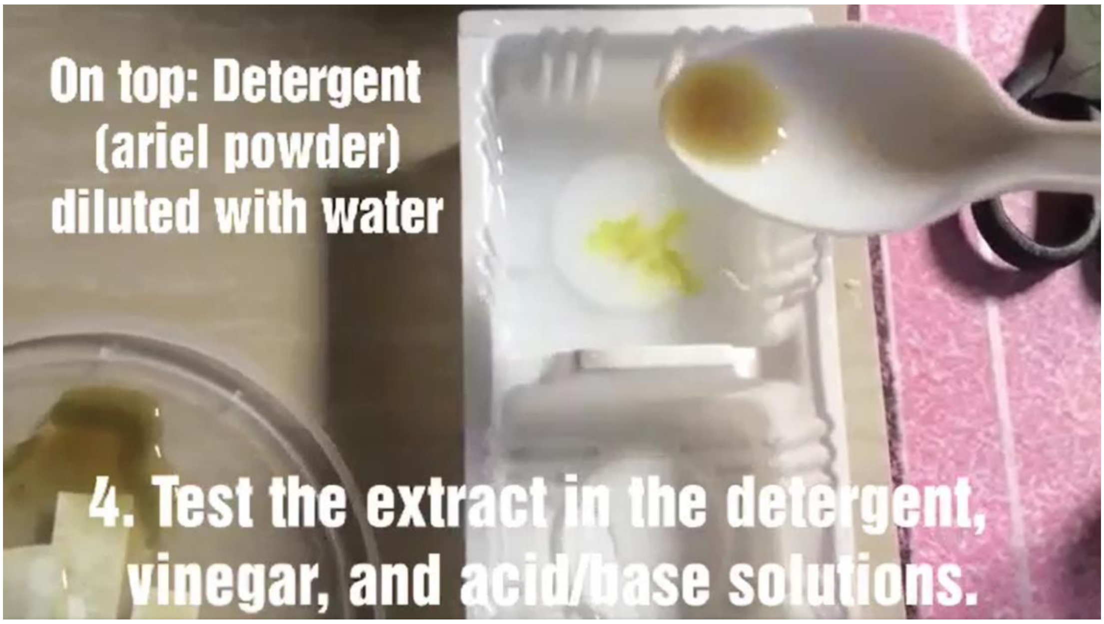

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