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Utilization of Plant Material Extracts as Natural Acid-Base Indicators: An Example of At-Home Lab Experiment in the New Normal Learning Set-Up

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Abstract

In response to the remote learning and teaching setup in science due to the COVID-19 pandemic, a lab at-home experiment was conducted where various plant materials were prepared and used as natural acid-base indicators for various household substances. The experiment is designed for the students to apply the fundamentals of intensive laboratory for science education: laboratory safety, laboratory apparatus, laboratory techniques, data documentation, and lab report writing. Presented herein are the results obtained during the experiments conducted at home that focused on the application of various plant extracts as natural indicator. Observable color changes showed that the tested plant extracts responded to the acidity and alkalinity of the various household substances. The science behind the color changes is attributed to the presence of various phytochemicals that change colors when protonated and deprotonated. The potential of the results obtained in the experiments is very promising as it can be further developed and optimized to an analytical procedure that can be applied in testing of acidity and alkalinity in various applications such as food safety and quality, environmental monitoring, materials testing, pharmaceutical analysis, and clinical diagnostics. Moreover, the experiment explored here presented lab teaching strategies that can be applied in the remote learning setup: formulate and design a home-based laboratory experiment that will cover the underlying scientific theories and skills and provide the students the opportunity to explore, improvise, apply, and present information that will holistically develop them as science educators for their current and prospective students.

Keywords: Acid-base chemistry; Lab at-home, Natural indicators, Plant materials, Remote learning

1. Introduction

The COVID-19 pandemic caused a shift in teaching and learning modality that resulted in abrupt changes in teaching strategies, specifically in administering laboratory experiments (Guidote, 2020). Several strategies have been employed, such as virtual labs, simulations, and test kits as alternatives to laboratory experiments. Studies showed that the students' understanding was similar either in person or online, attributing that virtual lab simulations are helpful (Babinčáková & Bernard, 2020). Moreover, time, money, and chemical wastes are saved and reduced. However, these strategies are costly, not readily available, and require high-tech equipment (Ibarra-Rivera et al., 2020). The importance of hands-on experiences to scientific procedures is the motivation

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for practical work setup at home, which is outside the fully stocked laboratory (Caruana et al., 2020). In general, the incorporation of laboratory work in science instruction is derived from the need to produce scientifically skilled professionals that will work in the academe, industry, and research institutions (Nguyen & Keuseman, 2020). Further, the learning experience became more engaging, even for nonscience majors, when students could conduct laboratory experiments at home. In this narrative, the Master of Arts in Teaching major in General Science and Technology students enrolled in the subject Intensive Laboratory Course in Integrated Science for the 2nd semester of 2021-2022 were assigned to perform a lab at-home activity to assess extracts of various plant materials as natural acid-base indicators. The lab at-home activity integrates the various laboratory aspects discussed throughout the semester – lab safety, common laboratory apparatus, basic laboratory techniques, and writing and documentation of laboratory reports.

An acid-base indicator is any substance that is used to detect pH levels that is based on the presence or concentrations of hydronium (H_3O^+) or hydroxide (OH^-) ions in sample solutions with corresponding color changes (Senathirajah et al., 2017). The use of plant materials as acid-base indicators have been recently investigated due to advantages over synthetic indicators such as availability of sources, cost-effectiveness, and non-hazardous properties (Sampin et al., 2019). The ability of plant materials to produce sharp end points is attributed to the presence of various pigments distributed in leaves, fruits, vegetables, and flowers (Vijayanand & Khalid, 2019). Moreover, the strategy of using natural indicators in acid-base analysis adopts the principles of green chemistry and the application of the concept of Education for Sustainable Development (ESD) which consists of environmental, economic, and social pillars for future generations (Stephanie et al., 2020).

In this qualitative investigation, local plant materials were extracted and tested for various common substances available in each household. The results of the observation were hereby compiled and aimed to add to the pool of knowledge in the literature about the application of plant materials as natural indicators for the determination of acidity and alkalinity of various substances.

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Moreover, the presented protocol can be used by science teachers to implement a lab-at-home experiment utilizing locally available materials and kitchen reagents.

2. Methodology

2.1. Extraction of Plant Materials

Various plant materials were gathered to be used as natural acid-base indicators (Table 1). These plant materials were locally sourced and readily available in the provinces of Nueva Ecija, Pampanga and Bulacan, and the city of Manila. The preparation of the plant extracts was based on the reported protocol by Sanchez et al. (2021) with slight modifications. In brief, cleaned pieces of the fresh plant materials were macerated with 10-20 mL of distilled water to extract the plant juices. To obtain intensely-colored extracts, it is recommended to use more of the plant material than the extraction solvent. The plant extract is filtered and stored in a clean container prior to use.

Table 1 Plant materials used in the experiment.

• Plumeria flower (locally known as kalachuchi) • Roast potato plant fruit (locally known as matalinta	• Ixora flower (locally known as santan) • Moringa leaves (locally known as malunggay) • Red cabbage	• Bougainvillea flower • Eggplant peelings • Butterfly pea flower	• Hibiscus flower (locally known as gumamela) • Coleus leaves (locally known as mayana) • Chili fruit

2.2. Application of Plant Extracts as Natural Acid-Base Indicators

In a test tube, watch glass, plastic container or spot plate, 2-3 drops of the plant extracts and 2-3 drops of the household substances were mixed. Note the initial color of the plant extracts, and observe the color changes after mixing the contents. The household substances that can be used for the qualitative

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observation are calamansi and lemon fruit juice, baking powder, baking soda, softdrinks, liquid bleach, detergent solution, shampoo, and vinegar.

2.3. Safety Precautions and Waste Disposal

The hazards were minimal since the experiment was designed to be conducted at home. Water as a benign solvent was used for the extraction instead of an organic solvent. No heat is required during the extraction of the plant extracts. Liquid bleach must be handled with care since these substances may cause burns when they come into contact with the skin and eyes. Thus, goggles, gloves, masks, and laboratory gowns must be worn while doing the experiments. After the experiment, the test solutions could be safely washed down the sink and disposed of in the trash.

3. Results and Discussion

Based on the experiments conducted, the tested plant material extracts were able to exhibit color changes in household substances with varying pH (Table 2). Vinegar, softdrinks, calamansi, and lemon fruit juice are acidic substances. While shampoo, detergent, baking powder, baking soda, and liquid bleach solutions are basic solutions. The changes in the color of the plant extracts when mixed with various substances with different pH levels are attributed to the presence of various phytochemicals such as anthocyanins, chlorophyll, betalains, carotenoids, and flavonoids (Kapilraj et al., 2019; Zheng et al., 2022). For instance, anthocyanins undergo chemical transformations upon changes in the pH of the environment with corresponding color changes (Figure 1) (Zheng et al., 2022). Anthocyanins are reddish and stable under acidic conditions, which are in the form of flavylium. While under basic conditions, the anthocyanins are yellow due to the transformation to chalcones. The transformation is due to the protonation or deprotonation that shifts the equilibrium towards the corresponding form of anthocyanin (Galingana & Organo, 2016).

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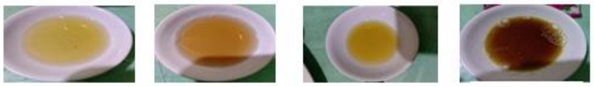
Table 2 Colorimetric responses of the plant extracts in various household substances. Images were from the students' individual lab reports.

Plant Material	Initial Color of the Plant Extracts	Observable Responses of the Plant Extracts to Various Household Products
Plumeria flower (locally known as kalachuchi)		 Baking Powder; Bleach; Vinegar; Softdrinks; Calamansi juice; Shampoo
Roast potato plant fruit (locally known as matalinta)		 Vinegar; Detergent powder; Baking powder; Liquid bleach
Ixora flower (locally known as santan)		 Vinegar; Calamansi juice; Detergent solution; Calamansi juice; Detergent solution; Vinegar
Moringa leaves (locally known as malunggay)		 Vinegar; Shampoo; Detergent solution
Red cabbage		 Vinegar; Calamansi juice; Shampoo; Softdrinks; Detergent solution; Liquid bleach
Bougainvillea flower		 Baking soda; Lemon juice; Detergent solution; Liquid bleach; Vinegar; Calamansi juice; Liquid bleach; Baking soda; Vinegar
Eggplant peelings		 Liquid bleach; Detergent; Vinegar
Butterfly pea flower		 Vinegar; Baking soda; Calamansi juice
Hibiscus flower (locally known as gumamela)		 Calamansi juice; Detergent; Liquid bleach; Vinegar; Softdrinks
Coleus leaves (locally known as mayana)		 Vinegar; Softdrinks; Calamansi juice; Detergent
Chili fruit		 Baking powder; Detergent solution; Calamansi juice; Vinegar

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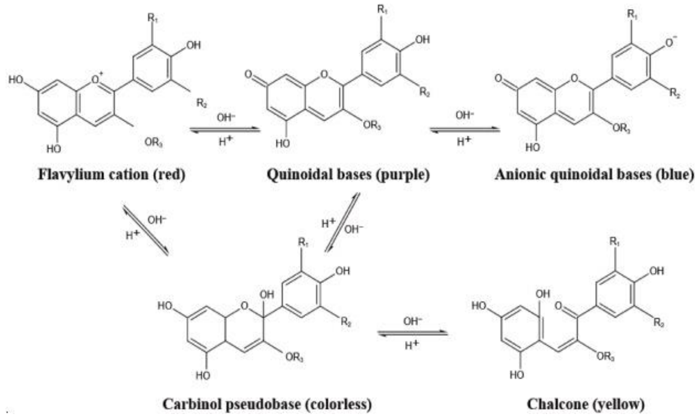

Figure 1 Forms of anthocyanin in various pH conditions (Zheng et al., 2022).

Anthocyanins have been reported to be present in butterfly pea flowers (Diaconeasa et al., 2020), red cabbage (Diaconeasa et al., 2020), plumeria (Diaconeasa et al., 2020), eggplants (Diaconeasa et al., 2020), hibiscus (Diaconeasa et al., 2020), roast potato plant (Sanjay et al., 2019), and ixora (Patil & Datar, 2015). The mayana and moringa leaf extracts are based on the chlorophyll of the plants (Bernardo & Organo, 2014; Zheng et al., 2022). The bougainvillea extracts were reported to have betalains (Kapilraj et al., 2019). While carotenoids are attributed to the color of chili (Villa-Rivera & Ochoa-Alejo, 2020). The changes in the color of the resulting mixtures vary depending on the plant extracts used, as observed from the results of the experiments. Nevertheless, the preliminary results obtained in this lab at-home experiment provide additional information to the existing literature regarding natural acid-base indicators.

The students were given the opportunity to obtain the relevant learning and skills training from conducting the lab-at-home experiment (Sanchez et al., 2021). Students were able to conduct the experiment firsthand and were allowed to explore their backyards and their communities to look for the plants that could be used as the source of indicators. The concepts taught prior to the experiment served as the foundation for the conduct of the home-based laboratory experiments. The students were able to apply the skills learned during the discussion of basic lab techniques such as the measurement of volume, extraction, filtration, mixing, and preparation of aqueous solutions. The students are encouraged to find materials available at their respective houses, become resourceful and instill the spirit of improvisation (Caruana et al., 2020). Moreover, the students were able to develop the values necessary to accomplish the assigned task, which equipped them with mastery and competence in the science topic. The results of the experiment shed light on the lab teaching strategies that can be applied in the remote learning setup: formulate and design a home-based laboratory experiment that will cover the underlying scientific theories and skills and provide the students the opportunity to explore, improvise, apply, and present information that will holistically develop them as science educators for their current and prospective students.

4. Conclusions and Outlook

A simple home-based experiment focused on preparing and applying plant material extracts as natural acid-base indicators for qualitative acid-base analysis was conducted as a hands-on alternative to recreate an actual laboratory experiment. Home-based experiments are excellent strategies for delivering laboratory instruction, especially under the COVID-19 social distancing restrictions. The results showed that the plant extracts responded through the resulting mixtures with varying colors depending on the acidity and alkalinity of the sample media. The activity allowed the students to explore and improvise with materials they had in their homes. The current remote learning instruction imposed challenges, especially for hands-on laboratory experience. Thus, this experiment could also provide a good opportunity for the students and in-service teachers to plan and design alternative activities that can be used to improve their delivery of science instruction. As a proof-of-concept principle, the results obtained in this home-based experiment could provide baseline information about the utilization of extracts from plant materials as natural acid-base indicators. Further, the results can be translated to various analytical platforms for the quantitative analysis of acidity and alkalinity with a high degree of precision and accuracy.

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