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Development and Evaluation of Blue Ternate Flower (BTFEpP) and Bougainvillea Bract (BBEpP) as Novel Localized pH Paper Indicator

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Abstract. The increasing integration of technology into education requires innovative solutions, particularly in resource-constrained environments. Most low- and middle-income regions have several schools facing challenges brought on by inadequate resources for science education, which in turn lead to students' poor performance in the subject. To address this, educators in the Philippines have begun developing low-cost, locally sourced teaching materials. This study explores the development of localized pH paper (LpP) using the extracts obtained from blue ternate flowers (BTFEpP) and bougainvillea bract (BBEpP). By conducting controlled experiments, the research evaluates the sensitivity and effectiveness of these LpPs as compared to commercial pH paper. The findings suggest that locally developed pH papers can provide a cost-effective, environmentally friendly alternative for educational purposes, offering a viable solution for enhancing science learning in under-resourced schools. Furthermore, the FTIR analysis confirmed the presence of hydroxyl groups, aromatic compounds, and esters—key functional groups responsible for their pH-indicating properties. However, further studies are needed to conduct a structural analysis of these bioactive compounds using techniques such as nuclear magnetic resonance (NMR) spectroscopy and mass spectrometry. Given these promising outcomes, further research is recommended to assess the shelf life and long-term stability of these localized pH papers under various storage conditions.

Keywords: Acid-base indicator; Blue ternate; Bougainville; Localized pH paper; Natural indicator.

1.0 Introduction

In an era marked by rapid technological advancement, the education landscape must adapt accordingly. The 2019 report by the International Society for Technology in Education emphasized the need for a transformation in educational practices, stating that technology should be integrated into curriculum design to foster active and engaged learning among students. However, a lack of teaching and learning resources, along with inadequate facilities, can hinder students' learning experiences (Fia et al., 2022). This issue is particularly prevalent in many secondary schools, especially in low- and middle-income countries, where modern science laboratory equipment is often inaccessible (Opara, 2024). More than 60% of schools in these regions have limited resources for practical science education, which contributes to poor student performance (McEwan & Barlow, 2020).

This global issue is also evident in the Philippines. Due to a severe shortage of science teaching tools, Filipino teachers are turning to alternative sources, such as open-source educational resources and affordable science kits (Estipular & Roleda, 2018; Parochelin, 2023). According to Gonzales et al. (2022), these resources have the potential to bridge existing gaps. Research from the Philippine Institute for Development Studies (PIDS) also revealed that even schools with limited budgets can improve the quality of science education when they employ pedagogically sound methods and utilize locally developed innovative materials (Balbon, 2020; Darman et al., 2024). These efforts exemplify educational practices tailored to local conditions, focusing on research related to low-cost science kits and modular teaching aids made from localized materials. This approach enhances student interest, engagement, and understanding (Reyes, 2019; Gerald-Goins et al., 2021; Benong et al., 2024)). Additionally, using locally sourced natural indicators from plants and flowers (Mitarlis et al., 2019) in acid-base activities can significantly support both teachers and students.

Several studies have been conducted on various natural indicators extracted from different plants that can be used as acid-base indicators. These include aqueous hibiscus flower (Peralta et al., 2019), red cabbage (Pakolpakçıl et al., 2018), and purple sweet potato (Farida et al., 2024; Benong et al., 2024), as well as Bougainvillea (Bougainvillea sp.) (Pakolpakçıl et al., 2018) and butterfly pea, locally known as blue ternate (Koshy et al., 2022). Additionally, research has been conducted to examine the viability of natural extracts, such as those from red cabbage, turmeric rose, and beetroot (Jabeen et al., 2022), as well as butterfly pea (Syahirah et al., 2018), as potential pH indicators. However, there have been no studies on the development and comparison of bougainvillea flower extract (BFE) with blue ternate flower extract (BTFE) as potential localized pH papers (LpP). Therefore, this study was conducted to determine whether BFE and BTFE have the potential to serve as LpP. Moreover, this study also provided a locally sourced, cost-efficient, and sustainable LpP that offers an economic advantage over commercialized synthetic pH papers, enabling teachers and students to use it without budgetary constraints.

Furthermore, it was found that the color of Bougainvillea bracts is attributed to the varied contents and proportions of betacyanins and betaxanthins (Zhang et al., 2024). Additionally, anthocyanins are also present in both blue ternate (Syahirah et al., 2018) and Bougainvillea (Kenari & Razavi, 2022). Therefore, this study evaluates the presence of organic compounds in Bougainvillea Flower Extract (BFE) and Blue Ternate Flower Extract (BTFE) used in the LpP, utilizing Fourier Transform Infrared Spectroscopy (FTIR) analysis. This evaluation was crucial because the functional groups (hydroxyl, aromatic, and ester groups) directly influence the color-changing properties that are central to the pH-indicating performance of the localized pH paper (Benong et al., 2024). By analyzing the molecular composition of these extracts, the study established a clear correlation between their chemical properties and their effectiveness as eco-friendly alternatives to commercial synthetic pH papers.

2.0 Methodology

2.1 Research Design

The study employed an experimental design, utilizing BFE and BTFE to develop BFEpP and BTFEpP. Their changes were compared using standard pH levels from 1 to 14, with commercial pH paper serving as the control. This study facilitates a thorough evaluation of the BFEpP and BTFEpP's responsiveness to different pH levels, aiming to develop a viable, locally sourced alternative for pH testing. Moreover, the extracts were also analyzed for the potential presence of anthocyanin using FTIR Spectroscopy (PerkinElmer Spectrum IR).

Extraction of BTFE and BBE

The blue ternate flowers and bougainvillea bract were authenticated by three experts in the field of biology and were freshly washed and extracted with a slightly modified method from Wiyantoko and Astuti (2020). Using 90% alcohol with a 100:1 weight-to-volume ratio (100 grams to 1 mL). The flowers were then pounded using a mortar and pestle to facilitate the extraction process.

Construction of BTFEpP and BBEpP

The same extracted samples were used to create the BTFEpP and BBEpP by soaking prepared bond paper strips and then drying them in a preheated drying oven at 100 °C.

2.2 Research Analysis Procedure

The constructed BTFEpP and BBEpP were tested for pH evaluation by immersing the prepared BTFEpP and BBEpP strips (14 strips per LpP were prepared for 14 pH levels) in different pH standards for 1 minute. In contrast, five drops of pH standards were added to the different test tubes containing 2.00 mL of prepared BFE and BTFE (14 test tubes per flower extract were prepared). Consecutively, 14 strips of control were also immersed on the 14 pH standards. Moreover, the flower extracts used in constructing the LpPs were also analyzed for the potential presence of anthocyanin using FTIR Spectroscopy (PerkinElmer Spectrum IR)(Benong et al., 2024).

2.3 Ethical Considerations

The study ensured that the blue ternate flowers and bougainvillea bract were harvested sustainably without damaging the ecosystem or endangering the species. Proper disposal of any plant waste after the experiment was also observed to minimize environmental impact. The chemicals used in the test were stored and disposed of in accordance with local regulations and guidelines. Above all, the research did not involve any animals, ensuring that animal welfare concerns are not a factor.

3.0 Results and Discussion

3.1 Evaluation of Color Changes in the BTFEpP and BBEpP in Standard pH

The BTFEpP and BBEpP were subjected to pH evaluation using pH standards to determine the exact pH when color change occurs. They were also compared to the commercialized pH paper BTFE and BBE. The color of BTFEpP significantly changed when it was dipped in the pH 3-14 standard, while BBEpP changed its color significantly when dipped in the pH 13 and 14 standards. Color changes also occurred at pH levels 13 (from light green to yellow-green) and 14 (from light green to a yellowish hue).

Table 1. *Standard solution with pH range of 1-14 and the different color changes of different indicators*

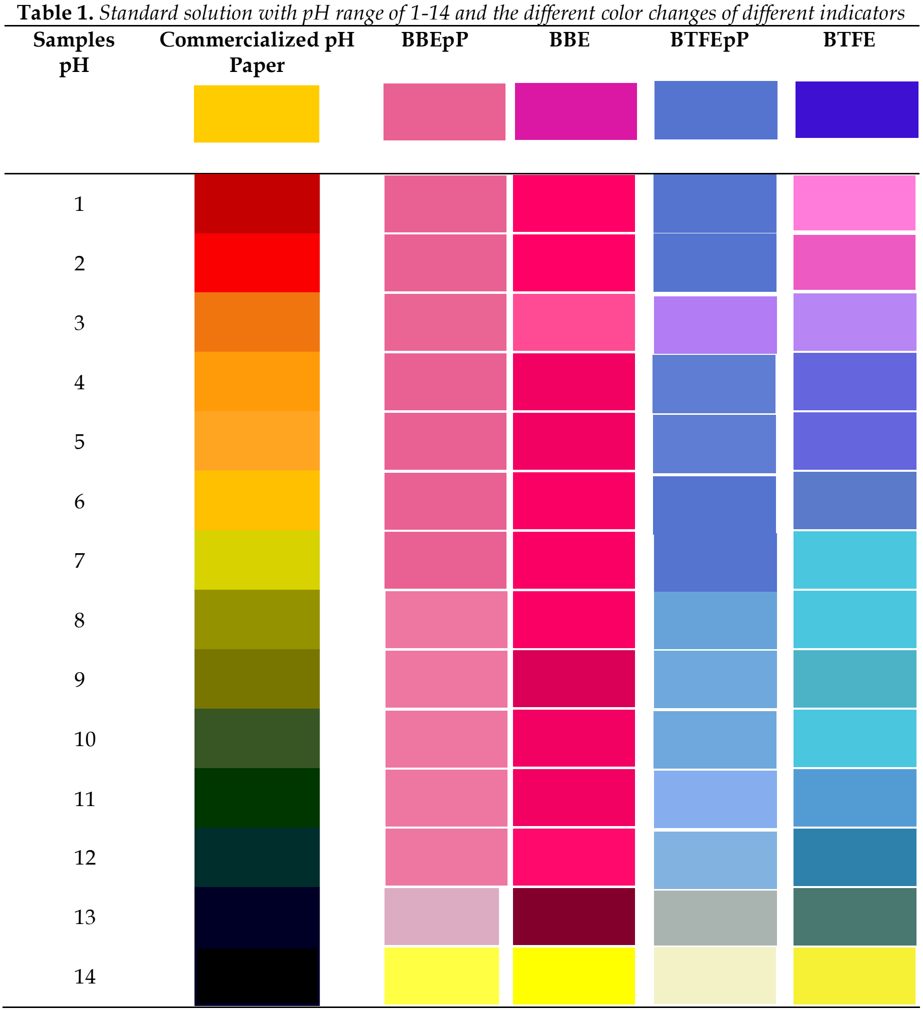

Table 1 presents an analysis of the pH paper derived from Blue Ternate flower extract (BTFEpP), which has demonstrated its effectiveness as a potent natural pH indicator across a range of 1 to 14. The crude extract of Blue Ternate, rich in anthocyanins, exhibits specific color changes comparable to those of commercial pH papers, confirming its reliability as a substitute. Previous studies, such as those by Gonzales et al. (2022) and Jabeen et al. (2022), have indicated that plant-based pH indicators can perform similarly to their synthetic counterparts. BTFEpP is an appropriate choice for an economical and environmentally friendly pH indicator, particularly useful in resource-constrained settings (Peralta et al., 2019; Pakolpakçıl & Çakır, 2018). Additionally, bougainvillea bract extract (BBEpP) has been found to function effectively as an acid-base indicator in the titration of strong acids and strong bases. Wang et al. (2024) identified genes associated with bract coloration, providing a valuable theoretical foundation for future gene cloning, genetic engineering, and breeding efforts aimed at enhancing Bougainvillea color diversity. The color variance observed in Bougainvillea bracts arises from variations in the content and proportions of betacyanins (which contribute to the purple color) and betaxanthins, resulting in a richer and more complex color, according to Zhang et al. (2024). Overall, this series of smooth color transitions through the pH spectrum makes Blue Ternate extract pH paper a valid and practical choice for many applications.

3.2 Evaluation of Color Changes in the BTFEpP and BBEpP mixed with Different Household Chemicals

Table 2 demonstrates the effectiveness of Blue Ternate Flower Extract pH Paper (BTFEpP) and Bougainvillea Bract Extract pH Paper (BBEpP) in detecting pH changes in household samples, such as cola and bleach, which exhibited significant differences.

Table 2. *Different color changes of different indicators after being dipped or mixed with 1mL of different household samples*

Sr No.	Sample	Commercialized pH paper	BTFLE	BTFLEpP	BBE	BBEpP
1	Starch					
2	Chocolate Drink					
3	Coffee					
4	Cologne					
5	Cola					
6	Bleach					
7	Energy Drink					
8	Shampoo					
9	Sugar					
10	Salt					
11	Milk Powder					

12	Flour
13	Toothpaste
14	Detergent Powder
15	Acetone Solution
16	Tea
17	Calamansi
18	Antacid
19	Vitamin C
20	Soy Sauce
21	Fabric Conditioner
22	Mouth Wash
23	Vinegar
24	Alcohol
25	Liquid Detergent
26	Lemon
27	Muriatic Acid
28	Multipurpose Cleaner
29	Lime and lemon soda
30	Pineapple Juice

Both localized pH papers demonstrated distinct and reliable color changes across various samples, performing comparably to commercialized pH paper. BTFEpP exhibited consistent, sharp transitions in acidic substances, such as cola, and basic substances, like bleach, while BBEpP displayed a broader range of color responses due to its anthocyanin and betacyanin content. These findings establish BTFEpP and BBEpP as cost-effective, sustainable, and practical alternatives for educational and everyday pH testing needs. The growing demand for dependable and cost-effective pH testing methods, particularly in educational and everyday settings, has driven the investigation of alternative solutions (Sanchez et al., 2021).

3.3 Presence of Bioactive Compounds from the Blue Ternate Flower and Bougainvillea Bract Extract

The FTIR analysis showed that the blue ternate flower extract exhibited five distinct spectral peaks within the wavelength range of 1044.55 cm^{-1} to 3312.83 cm^{-1}. The bougainvillea bract extract also has five distinct peaks within 1038.96 cm^{-1} to 3271.83 cm^{-1}.

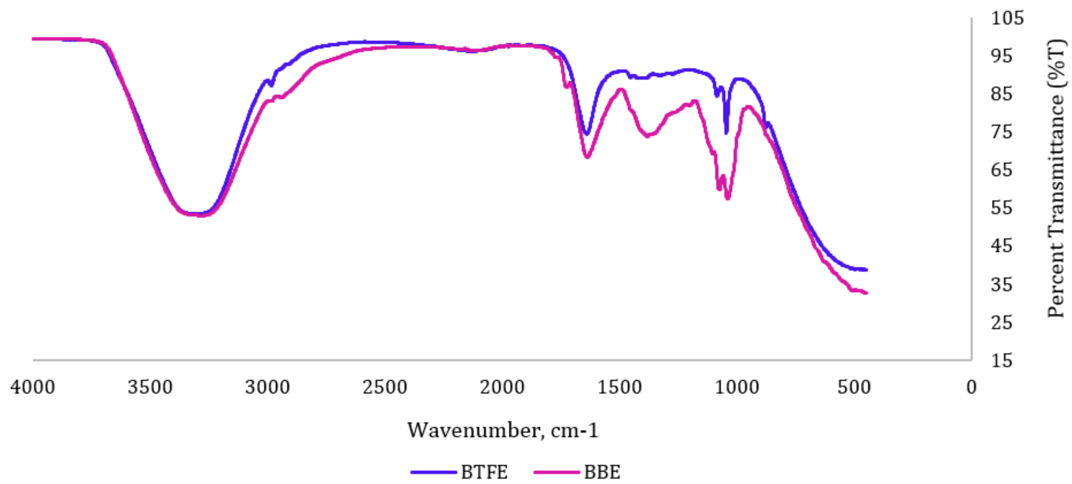

Figure 1. *FT-IR transmittance results from the blue ternate flower extract and bougainvillea bract extract*

The FTIR analysis of the Blue Ternate extract identified several important functional groups. A peak at 3312.83 cm^{-1}, with a transmittance of 53.49%, is attributed to hydroxyl groups (C-OH), indicating the presence of alcohols or phenols. Peaks at 1638.57 cm^{-1} and 1413.03 cm^{-1}, with transmittances of 74.44% and 89.02%, respectively, correspond to aromatic ring vibrations, suggesting a high concentration of aromatic compounds. Additionally, a peak at 1084.03 cm^{-1} (transmittance of 84.32%) is associated with ester groups (C-O), and a peak at 1044.55 cm^{-1} (transmittance of 74.75%) indicates C-O stretching vibrations. These results reveal a diverse chemical composition, characterized by prominent aromatic, hydroxyl, and ester functionalities, which may impact the extract's properties and applications. The detailed results are summarized in Table 3 below.

Table 3. *Noticeable peaks produced from the FT-IR Transmittance result*

Peak Number	Wave number (cm^{-1})	Percent Transmittance (%T)	Functional Group
Blue Ternate Flower Extract			
1	3312.83	53.49	Hydroxyl (C-OH)
2	1638.57	74.44	Aromatic
3	1413.03	89.02	Aromatic
4	1084.03	84.32	C-O, C=O, C-OH
5	1044.55	74.75	C-O
Bougainvillea Bract Extract			
1	3271.83	53.03	Hydroxyl (C-OH)
2	1636.03	68.26	Aromatic
3	1383.26	73.85	C-O, C-H, C-N
4	1074.74	59.80	C=O, C-OH
5	1038.96	57.53	C-O-C

The FTIR analysis of blue ternate flower extract identified various functional groups, hydroxyl, aromatic, and ester, contributing to the various applications of this extract. The absorbance at 3312.83 cm^{-1}, due to hydroxyl groups, indicates the presence of either alcohols or phenolic groups. Hydroxyl groups have been recognized as antioxidants due to their ability to donate hydrogen atoms to neutralize free radicals. It is further justified by recent research, including the study by Chen et al. (2020), which identified that hydroxyl groups of phenolic compounds demonstrate remarkable antioxidant activity, expressing their potential health value for blue ternate extract. Peaks observed at 1638.57 cm^{-1} and 1413.03 cm^{-1}, which are attributed to the vibrations of aromatic rings, indicate a high concentration of aromatic compounds (Mathai et al., 2021). These compounds of blue ternate have been previously reported to possess antimicrobial and anti-inflammatory properties (Nascimento et al., 2021). This finding supports the potential use of the extract as a therapeutic agent. The peak at 1084.03 cm^{-1} is assigned to ester groups. It is worth noting that esters are commonly used in the food and cosmetic industries due to their aromatic properties and stability. Recent studies, including the study by Lu et al. (2024), emphasize the significance of esters in flavoring and fragrance. Additionally, the C-O stretching vibrations at 1044.55 cm^{-1} ultimately define a complex chemical structure that contributes to the versatility of the extract. These FTIR results were aligned with those of Turno (2021), which indicate that blue ternate flower extract contains anthocyanin. Moreover, the findings suggest potential industrial applications for blue ternate flower extract (Multisona et al., 2023).

The FTIR spectrum of the bougainvillea bract extract revealed significant functional groups, including hydroxyl, aromatic, ester, and C-O stretching vibrations. These findings are consistent with those of Sahu and Saxena (2013), who discovered the presence of phenolic compounds and flavonoids in both bougainvillea flower and bougainvillea bract extract samples through FTIR spectroscopic analysis. Aromatic peaks at 1636.03 cm^{-1} and 1383.26 cm^{-1} also align with the study by Zhang et al. (2023), which established the presence of aromatic rings in bioactive plant extracts as possessing antimicrobial activity. Moreover, according to Wu et al. (2022), the color of bougainvillea bracts is attributed to varying levels of betacyanins and betaxanthins, which both share similar functional groups. Therefore, further studies are needed to conduct a structural analysis of these bioactive compounds using techniques such as NMR (Nuclear Magnetic Resonance) and mass spectrometry.

4.0 Conclusion

The findings of this study highlight the potential of BTFEpP and BBEpP as effective natural pH indicators, demonstrating comparable performance to commercially available pH papers. FTIR analysis confirmed the presence of hydroxyl groups, aromatic compounds, and esters—key functional groups responsible for their pH-indicating properties. Experimental tests further validated the reliability of BTFEpP and BBEpP, which exhibited consistent and well-defined color changes across the entire pH spectrum (1–14). These results suggest that localized pH papers (LpP) derived from natural sources, such as blue ternate flower extract and bougainvillea bract extract, can serve as viable alternatives to synthetic indicators, offering both environmental sustainability and economic benefits, particularly in resource-limited settings. Given these promising outcomes, further research is recommended to assess the shelf life and long-term stability of these localized pH papers under various storage conditions. Additionally, future studies should explore other natural extracts with potential pH-indicating properties to enhance the effectiveness and applicability of LpPs. Expanding this research could contribute to the development of sustainable, cost-effective, and eco-friendly alternatives for scientific and educational use.

5.0 Contributions of Authors

All the listed authors have equally and significantly contributed to all aspects of this study, including study conception and design, data analysis and interpretation, and manuscript drafting and editing. Mrs. Cherry May B. Rodriguez and Ms. Daneth Joyce L. Gumahad analyzed the results, developed a comprehensive methodology to synthesize and test the pH indicators, and connected their research findings with relevant literature to emphasize the significance and novelty of the study. Mr. Andray Pollente, Mr. Dharell Cervantes, Mr. Phil Christian Fernandez, and Mr. Joefaith Endam all contributed to this study by preparing samples, calibrating pH indicators, and evaluating performance under various conditions. Mr. Christopher Bernard Benong proofread the manuscript and supervised all stages of the research, providing critical guidance to ensure alignment with the study's goals. Additionally, Mr. Jesson B. Belen was involved in formulation, assessment, experimentation, and data collection. All authors read and approved the final draft of the manuscript.

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7.0 Conflict of Interests

All authors declare that they have no conflicts of interest related to this study.

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