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Exploring Plant Species in Vietnam for the Production of pH Indicator Paper

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ABSTRACT

Purple cabbage, turmeric, magenta, amaranth, and red beet contain colour anthocyanins. These colours change according to pH environments. This research aims to explore the potential of utilizing various plant species, such as purple cabbage, turmeric, magenta, amaranth, and red beet, to develop pH indicator paper. The colour solutions of these plants were extracted with deionized water. The extracted solutions were analyzed by IR spectra and UV-Vis spectra. The peak of OH, C=O, and C-O in IR spectra changed in alkaline, neutral, and acidic environments, respectively. The maximum absorption wavelengths of the extracted solutions in UV-Vis spectra were 533 nm and 600 nm in alkaline and neutral environments, respectively. The pH indicator paper was created by impregnating plain white computer paper with extract solutions to achieve uniform colouration. These prepared pH indicator papers were used to detect the pH of household chemicals, including milk, soap, toothpaste, and various fruits and vegetables. The study demonstrates that these plant species exhibit excellent sensitivity to different pH values, possess good durability, and remain unaffected by environmental factors. The developed pH indicator paper holds promising practical applications for testing the pH of diverse chemicals. In this study, the pH indicator paper was employed to determine the acidity or alkalinity levels of commonly found household items, including fruits, beverages, and cleaning solutions. The results highlight the versatility and convenience of utilizing plant-based pH indicator paper for monitoring pH variations in daily life applications.

Keywords: purple cabbage, turmeric, magenta, amaranth, red beet, pH indicator

Introduction

The pH of aqueous solutions is an incredibly significant parameter that plays a crucial role in a wide range of applications.[1] The most widely used technique to determine pH is potentiometry, utilizing a combined glass pH electrode. However, one drawback is the limited long-term stability of this instrument, which necessitates frequent calibration and cleaning of the glass frit that forms the liquid junction with the reference electrode.[2] Currently, a variety of synthetic compounds or man-made organic indicators are used for pH determination, such as litmus paper, pH paper, phenolphthalein, methyl red, methyl yellow, and pentamethyl red.[3] The drawbacks of these kinds of indicators include the potential for hazardous consequences, effects on the environment, high costs, restricted availability, and occasionally limited colour changing range.[4,5]
Anthocyanin (red colour) is a natural organic compound and found in many types of plants.[6,7] Anthocyanin is non-toxic and its concentration has no limits on food.[8,9] The colour of anthocyanin changes according to the pH environment. These natural pigments undergo distinct colour changes in response to changes in pH levels, providing visible and identifiable indicators.[10] Furthermore, these plant-based pH indicators demonstrate impressive durability and resistance to environmental factors and can be used in the long term.[11,12]

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Another significant advantage is the ease of accessibility and affordability of these plant species.
The potential of plants such as purple cabbage, turmeric, magenta, amaranth, and red beet allows for the creation of pH indicator paper because they contain various organic compounds such as anthocyanins, curcumin, flavonoids, betaine, carotenoids, and flavones, which are accountable for the transition of protons.[13,14,15] Located in the tropics, Vietnam has an abundance of vegetation in which there are many types of plants capable of being extracted for colorants. However, as there has been no general research on extracts from such plants to create pH indicators, it is essential that the study on a natural pH indicator paper be conducted.

Materials and Methods

Chemicals
The pH standard solutions were purchased from Merck, Darmstadt, Germany.
The plain white computer paper (A4 70/90 Double-A) was purchased from Vinh Thinh Paper Industry Co., Ltd, Vietnam.
Deionized water was purchased from WASOL CORP, Vietnam.

Collection of plant materials
The selected plants for making pH indicator paper were among common vegetables in daily human meals (Table 1). They were purchased from a local market in Ho Chi Minh City, Vietnam on 11st March, 2023, which is located between 10º10' and 10º38' North latitude and 106º22' and 106º54' East longitude. Prior to the extraction, the plant samples were washed, dried and crushed to a fine powder (0.5 - 1.0 mm) in a coffee grinder (HC-100, China) before extraction.

Preparing extracted solutions
To prepare an extracted solution, classical solvent extraction was used to extract anthocyanin compounds from the collected plants. Separately, 250 g of purple cabbage, 20 g of turmeric, 250 g of magenta, 500 g of

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amaranth, and 500 g of red beet were boiled in each 100 mL of deionized water for 15 minutes. These extracts were filtered using Whatman filter paper after being allowed to cool to 25ºC.

IR and UV-visible Analysis of the extracts

The extracted solution from purple cabbage in an alkaline, neutral, and acidic environment was measured by attenuated total reflection-Fourier transform infrared spectroscopy (ATR-FTIR) and UV-Vis absorption spectroscopy. The FTIR spectra were recorded to be between 4,000 and 500 cm^{-1}, using 16 scans for each spectrum with a resolution of 4 cm^{-1}. Spectral acquisition was completed using the Spectra Manager, Version 2. The intensity of the UV-Vis spectra was recorded in a range between 200 and 800 nm in a 1 cm quartz cuvette with slit widths for the excitation at 2 nm.

Preparation of pH paper Indicator strips

Plain white computer paper was submerged in an extracted solution for 20 minutes to achieve uniform colouration. It was subsequently air dried for 12 hours. The impregnation and drying stages on the coloured sheets were performed triplicates, and the sheets were cut into strips measuring 7.0 cm in length and 1.5 cm in width (Table 2).

Building palettes of pH paper indicator strips

As prepared previously, the pH indicator paper strips were used to build colour palettes of pH standard solutions ranging from 1 to 14. The pH values of these standard solutions were kept stable by utilizing a universal buffer solution with a pH range of 1 to 14. [9]

Determining the pH of different household chemicals

The pH indicator paper strips were used to detect acid-base properties in household chemicals, including milk, soap, toothpaste, and various fruits and vegetables. The results were compared to the standard method using a pH meter.

Table 1. Plant species selected as raw materials for the preparation of the indicator papers

No.	Local name	English name	Botanical name	Plant parts used
1	Bắp cải tím	Purple cabbage	*Brassica oleracea; Brassicaceae*	
2	Nghệ	Turmeric	*Curcuma longa; Zingiberaceae*	
3	Lá cẩm	Magenta	*Peristrophe; Acanthaceae*	
4	Rau dền đỏ	Amaranth	*Amaranthus tricolour; Amaranthaceae*	
5	Củ dền	Red beet	*Beta vulgaris L.; Chenopodiaeae*	

Table 2: pH indicator strips of purple cabbage, turmeric, magenta, amaranth, and red beet

Purple cabbage	Turmeric	Magenta	Amaranth	Red beet
				

Results and Discussion

FTIR and UV-Vis properties in the solutions

The IR spectra of the purple cabbage extract in an alkaline, neutral, and acidic environment are shown in Figure 1. In an alkaline environment, the characteristic signals can be seen: 3455.87 cm^{-1} for the peak signal of the O-H stretching modes, 1636.25 cm^{-1} for one signal of the C=O stretching modes, 1415.74 cm^{-1}, a weak signal, for the C-O stretching modes, and 666.20 cm^{-1} for a signal of the C-H bending modes in the aromatic ring. In a neutral environment, the results showed typical signals: 3425.10 cm^{-1} for the O-H stretching modes, 1641.34 cm^{-1} for the C=O stretching modes, 1066.35 cm^{-1} for the C-O stretching modes, and 671.35 cm^{-1} for the C-H bending modes in the aromatic ring. In an acidic environment, the results show characteristic signals: 3700-3000 cm^{-1} for two strong signals, which are the O-H stretching modes; 1796.96 cm^{-1} is the C=O stretching modes; 1643.57 cm^{-1} is the C-O stretching modes; and 900 - 500 cm^{-1} is the C-H bending modes in the aromatic ring. The IR spectra of purple cabbage extract in different conditions show that the positions of the bonds of OH, C=O, C-O, and C-H shift when the pH value varies.

Figure 2 shows that the wavelength max 533 nm represents the maximum absorption of the purple cabbage extract sample in an acidic environment (pH 1 line). The wavelength max 600 nm represents the maximum absorption of the sample in a neutral environment (pH 7 line). At pH 14, absorption declines progressively in the wavelength range 400 - 800 nm and cannot be calculated as wavelength max (pH 14 line). As a result, in different pH conditions, the absorbance of the colour extract changes in proportion to its colour. The changes in wavelength max of purple cabbage extract were similar to previous studies.[16,17,18]

Determination of the colours of the indicators with the pH range

After completing the fabrication phase of the pH indicator paper strips, the colours were coded in solutions with different pH values ranging from 1 to 14. The results showed distinct colour changes for all surveyed plant species in both acidic and alkaline environments. Specifically, turmeric and red beet exhibited colour changes from red to yellow when shifting from an acidic to an alkaline environment. On the other hand, purple cabbage and magenta displayed unique colour changes in solutions with different pH levels. In solutions with pH values ranging from 1 to 3, purple cabbage showed a red colour; in solutions with pH values ranging from 4 to 12, it turned dark green; and in solutions with pH values of 13 and above, it changed to yellow. With magenta as the extracted pH indicator, it appears reddish-orange in solutions with pH 1 and 2, light green in solutions ranging from pH 3 to 9, and deep green in solutions with pH values of 10 or higher. The colour change for the amaranth indicator was as follows: in solutions with pH values ranging from 1 to 10, the solution was pink with varying shades depending on the specific pH value, and in solutions with pH 11 and above, the solution turned yellow. The specific colour changes of the indicators in

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solutions with different pH values are shown in Table 3. The changes in the colours of these pH indicator paper strips were similar to previous studies.[9,19]

Determination of the colours of the indicators with different foods

The pH indicator papers made from various plant species were utilized to determine the pH values of common household food items. Food items with pH values ranging from 2 to 11 exhibit different colours when using pH indicators prepared from the surveyed plant species. The results showed distinct colour changes of the indicators for each type of food due to variations in pH values. The food had rapidly been prepared from common household plant species. The specific results regarding the colour changes of the pH indicator paper strips in different types of food are presented in Table 4.

Determination of the colours of the indicators with household cleaning solutions

The testing was expanded to essential household cleaning solutions. These solutions are primarily alkaline, with pH values ranging from 6 to 14. Each type of the prepared indicators exhibited different colour changes corresponding to the pH value of each solution. In solutions with pH values raning from 6 to 12, the indicators made from purple cabbage and magenta appeared blue, while the indicators made from turmeric and red beet appeared reddish orange. For cleaning solutions with pH values of 12 and above, all the indicators made from purple cabbage, turmeric, amaranth, and red beet turned into the lemon-yellow colour, while the indicator made from magenta turned out to be deep green. The specific colour changes of the indicators in household solutions are presented in Table 5.

The results obtained when testing these indicator strips with solutions of different pH values have been verified using pH measurement devices, confirming the reliability of using plant-based indicators for pH determination.

Conclusion

The results presented here demonstrate the feasibility of preparing paper indicator strips for testing the pH values of different sample objects using plant species closely related to daily life. The preparation process is simple, fast, and cost-effective. The plant species chosen in this study, including purple cabbage, turmeric, amaranth, and red beet, have shown distinct colour changes when tested with sample objects of different pH values. Depending on the structural characteristics and constituents extracted from each plant species, different colour changes were observed. The colour stability of these indicators over time has also been confirmed. The findings of this study can be extended to application in other chemical practices, such as replacing synthetic indicators in acid-base titration procedures.

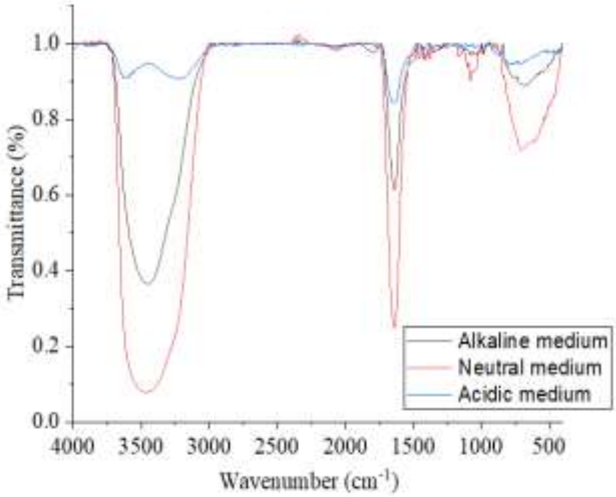

Figure 1: The IR spectrum of purple cabbage extract in different pH

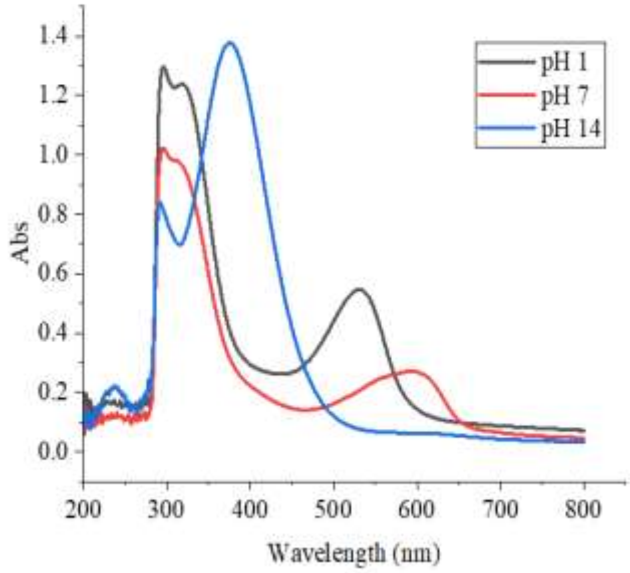

Figure 2: Investigation of the maximum absorption wavelength of purple cabbage extract in different pH

Table 3: The specific colour changes of the indicators in solutions at different pH values

pH	The colour of pH-paper indicator strips				
	Purple cabbage	Turmeric	Magenta	Amaranth	Red beet
1					
2					
3					
4					
5					
6					
7					
8					
9					

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10					
11					
12					
13					
14					

Table 4: The colour changes of the indicators with different food items

Sample	The colour of pH-paper indicator strips					The pH value from pH meter
	Purple cabbage	Turmeric	Magenta	Amaranth	Red beet	
Asparagus						11.2
Lemon						2.1
Watermelon						9.3
Celery						10.1
Apple						8.6
Vinegar						3.3
Tomato						4.7
Coffee						6.7
Coca cola						3.5
Graph						8.2
Ice cream						4.1
Milk						6.8
Beer						5.4

Table 5: The colour changes of the indicators with different household solutions

Sample	The colour of pH-paper indicator strips					The pH value from pH meter
	Purple cabbage	Turmeric	Magenta	Amaranth	Red beet	
Baking soda						8.4
Toothpaste						9.1
Facewash						6.6
Household detergent						11.3
Soap						12.3
Kitchen cleaner						13.5
Drain cleaner						14.1

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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