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A study on Using Plant Extracts as Indicators for the Endpoint in the Acid-Base Titrations

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A B S T R A C T

Acid-base titrations are the key part of volumetric analysis in the first year undergraduate chemistry practical program in Libya. Students are typically taught the procedures and skills necessary for acid-base titrations utilizing chemically synthesized indicators. Frequently utilized Synthetic indicators are sometimes difficult to obtain and highly hazardous to both people and aquatic life. Thus, the best option is to use natural dyes because it has been illustrated that some plant extracts exhibit the characteristics of synthetic dyes, making them usable for their use. Since this research emphasizes a return to green chemistry, it was necessary to search for alternative environmentally friendly indicators that are readily available, simple to prepare, and can be used to detect the endpoint of the reaction. The purpose of this article is to explore nine different types of aqueous extracts from various plants that can be used as indicators in acid-base titrations. The results have show that, similar to phenolphthalein, all of the investigated plant extracts are appropriate for strong-acid and strong-base titration. Moreover, hibiscus flower and cabbage leaf extracts are superior indicators for a strong-acid and strong-base titration to the synthesizers indicators. It is recommended that the use of these plant extracts as acid-base indicators should be combined in the teaching of acid-base titration. The amount of sodium hydroxide consumed at the endpoint were between 9.5 - 10 mL, while the pH of the solutions were between 6 - 9.7.

1 Introduction

Classical analysis methods are still sufficient and have many advantages, although the availability of instrumentational analytical techniques is offered for chemical analyses of various compound. (W. A. Izonfuo, Fekarurhobo, Obomanu, & Daworiye, 2006; Petrucci, 1972) Titration is among the standard analytical methods which are still used currently (Petrucci, 1972). The equivalence point in titration is often achieved by the endpoint titration which is characterized by indicators (W. A. Izonfuo et al., 2006; Mendham, 2004; Petrucci, 1972). The indicator is a chemical compound that is added during titration in a very small amount that causes a noticeable change in one of the physical or chemical properties of the solution and contributes to determining the endpoint of the titration. There are numerous types of indicators available for acid-base titration types (W. A. Izonfuo et al., 2006; Mendham, 2004; Petrucci, 1972). Commonly used acid-base indicators are synthetic organic dyes such as phenolphthalein, methyl red and methyl orange, phenol red, methyl yellow, bromophenol blue, thymol blue, and others. these indicators are usually expensive and have toxic effects on humans such as diarrhea, pulmonary edema, hypoglycemia, and pancreatitis, and can lead to abdominal cramps, rashes, eruptions, redness, and necrosis of the skin and cause environmental pollution (Kasture, 2005; Okoduwa, Mbora, Adu, & Adeyi, 2015). Thus, researchers have sought ways to measure the pH of solutions other than using synthetic pH indicators (Bhagat, 2008; W. A. Izonfuo et al., 2006). In much of the published research, many flowers, fruits, and vegetables have been used effectively as natural pH indicators (Abugri, 2012;

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Alejandre; Bhagat, 2008; Bhise, 204; W. F. Izonfuo, G. Obomanu, F., and Daworiye,L., 2006; Nuryanti, 2013; Okoduwa et al., 2015; Ologundudu, 2009; Pimpodkar, 2014; Vaibhav, 2014). Green indicators are pigments or dyes isolated from a variety of natural sources, including plants, fungi, insects, and algae. They were likely to be cheaper, environmentally friendly and non-toxic, readily available, easy to extract, less toxic to users, and environmentally friendly (Housecroft C. and A. G. Sharpe & 2008; Okoduwa et al., 2015; Pradeep, 2013). Almost any flower that is red, blue, or purple contains a class of organic pigments that change colour with pH [2, 4]. Natural dyes as acid-base indicators were first used in 1664 by Robert Boyle, nowadays, several studies conducted by different scientists have exploring the effectiveness of natural indicators in acid-base titration (Housecroft C. and A. G. Sharpe & 2008; Kadam, 2013; Okoduwa et al., 2015). Others are plants and leaves such as red cabbage extract, raspberry juice, black tea, beet juice, and tomato leaf. (Housecroft C. and A. G. Sharpe & 2008; W. F. Izonfuo, G. Obomanu, F., and Daworiye,L., 2006; Kadam, 2013; Okoduwa et al., 2015). From here, the natural indicator can be defined as a natural substance of plant origin that can be used to determine the pH of another substance (Kadam, 2013; Vaibhav, 2014). Plant pigments that provide natural food colours can be grouped into four primary classes based on their chemical structure, viz., chlorophyll, carotenoids, flavonoids, and betalain. Hence, this research aims to evaluate the properties of some colours natural plants to test the extent of their analytical capabilities as guides for acid and base titrations, tested plants are given in Table 1.

2. Materials and Methods

Materials and Instrumentation

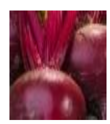
2.1 Chemicals and Instrumentations

The chemicals used are all of a high degree of purity and are produced by well-known companies: Sodium hydroxide (98%), hydrochloric acid (37%), and sodium carbonate (99.8%). a pH device (Thermo).

2.2 Preparation of Standard Solutions

100 mL of a standard 0.1 M (mol/L) sodium carbonate solution was prepared by the direct method, weighing 1.06 g in a 100 mL volumetric flask, the volume was completed with deionized distilled water up to the standard mark. Hydrochloric acid in a concentration (0.1 M) was prepared by taking 8.36 mL) from a bottle of concentrated acid (37%-1.81g/cm3-36.5 g/mol) in a standard volumetric flask (1000 mL) the volume was supplemented with deionized distilled water. It was confirmed that the acid concentration was adjusted by titrating it with an exact titration of sodium carbonate and a phenolphthalein index. Sodium hydroxide (0.1 M) was prepared by taking 4 g in a standard volumetric flask (1000 mL) the volume was supplemented with deionized distilled water. The control of sodium hydroxide was confirmed by titrating it with titrated hydrochloric acid and phenolphthalein index.

Table 1: Utilized plants to produce an aqueous extract for acid-base titrations

Plant	**Discerption**
	Hibiscus rosa-Sinensis are used for foods and beverages and as a food coloring agent, as they have been known to contain anthocyanins [18-16].
	Red cabbage has an anthocyanin pigment primarily used as a food color and can be used as a pH indicator in pharmaceutical formulations.
	Eggplant has a dark purple or black colour. it ranks among the top 10 fruits and vegetables for its high phenol content and antioxidant properties. The peel of purple eggplant is rich in anthocyanins.
	Beetroot red beets contain a high percentage of betalain. Betalain is a coloured substance that gives some vegetables, fruits, and flowers their colour.
	Capsicum fruit colors vary between green, yellow, red, orange, and yellow. Capsicum extract contains β-carotene, capsanthin, cryptoxanthin, lutein, zeaxanthin, and capsanthin. Capsanthin is a major carotenoid in red pepper.
	Tomatoes ranked as the main source of lycopene, followed by β-carotene and vitamins C. Lycopene and β-carotene is a major contributors to tomato fruit coloration [19].
	Lemon, the outer peel is a light green to yellow and consists of flavonoids, which contain carotenoid pigments, vitamins, and essential oils **[20]**.
	The poinciana tree (Red Acacia) has red flowers that have bioactive substances and antioxidants that are ideal for new natural anti-aging, hydrating, and hair treatments.
	***Pistacia Atlantica*** fruit is orange coloured a small fruit numerous research has proven that it is beneficial for anaemia and increases iron levels (Mahjoub F, 2018).

2.3 Preparation of the Plant Extract

All solutions of the different plant extracts were prepared by dissolving 3.4 gram of each plant (date, flower, or root) in 40 mL of deionized distilled water and shaken for 3 hours. It is used on the same day, and then the filter. From these extracts, drops are added before starting the titration. The color change was tested with titration.

2.4 Acid-Base Titrations for Strong Acid and Strong Base

The hydrochloric acid was first titrated with sodium hydroxide to determine the volume of base needed to reach the equivalence point, using both phenolphthalein and methyl orange indicators. The previous experiment is repeated, but this time by adding drops of different plant extracts, and the calibration is recorded in color before, at, and after reaching the equivalence point. The pH values are also recorded at the endpoint point.

2.5 Measurement of pH and (Uv-Vis) Spectra of Aqueous Extracts.

Stepwise additions of 2 Ml of hydrochloric acid (0.5 M) to 5 mL of the aqueous extract were made. Until a pH reached 1, the pH and UV-VIS spectrum were measured with each addition. Similarly, 2 mL of sodium hydroxide solution (0.5 M) is added progressively to 5 mL of the aqueous extract, with the pH and UV-VIS spectrum being recorded after each addition, until pH = 13.69. to calculate pH of 0.5 M NaOH. So, pOH = -log [OH-] = -log(0.5) = 0.3010 Hence, pH =14 - pH =13.69 .

3. Results and Discussion

The flower extract underwent testing to determine its suitability for use as an acid-base indicator in strong acid-strong base titrations. The screening results were comparable to those of conventional indicators methyl orange and phenolphthalein as collected in Table 2.

The endpoint of the aqueous extracts of the different plant extracts mentioned in Table 2 was also determined and it was compared with each of the indicators of methyl orange and phenolphthalein, and the results were included in Table (2) and Figure (1). It is assumed that the consumed volume will be 10 mL as expected by theoretical calculations of (10 mL), however, it is slightly different, these differences in 0.1 ml are due to the precision of the method. In addition, Table (2) includes a description of the colour of the endpoint.

The extracts of both hibiscus flowers and cabbage leaves were selected to study the change in acidity function when sodium hydroxide was added, due to the obvious change in colour at the neutralization point of these two extracts from pink to light green. 0.5 mL of NaOH was added each time and the corresponding value was recorded. As for the rest of the aqueous extracts, values were measured when the break-even point was reached, and the results were included in Table (2) and Figure (1).

Table 2: Screening results of acid-base titrations

Indicator		Color change at the End point	Burette reading (mL)	pH at the end point
Standard indicator	Methyl Orange	Red to yellow	9.9	8.6
	Phenolphthalein	Colorless to red	9.9	7.5
Plant extract	Cabbage Leaves	Pink to light green	9.7	8.3
	Acacia Flowers	Pink to light green	9.8	6.3
	Eggplant Peels	colorless to light brown	9.6	9.7
	Lemon Peels	colorless to light green	9.5	6
	Beetroots	light orange to light green	10	9
	Hibiscus Flower	pink red to light brown	10	8.4
	Red Pepper	colorless to light green	9.6	7.3
	Pistacia Atlantica Fruit	light brown to light yellow	9.7	6.7
	Tomato Fruit	light green to dark brown	10	9.5

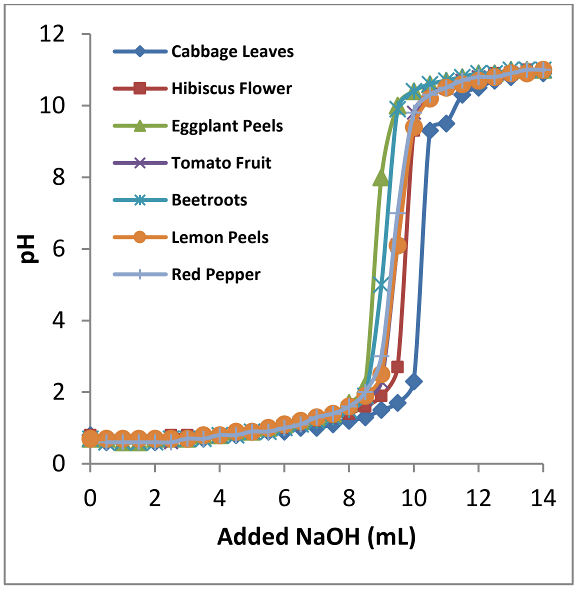


Figure 1: The change of the pH with the addition of NaOH

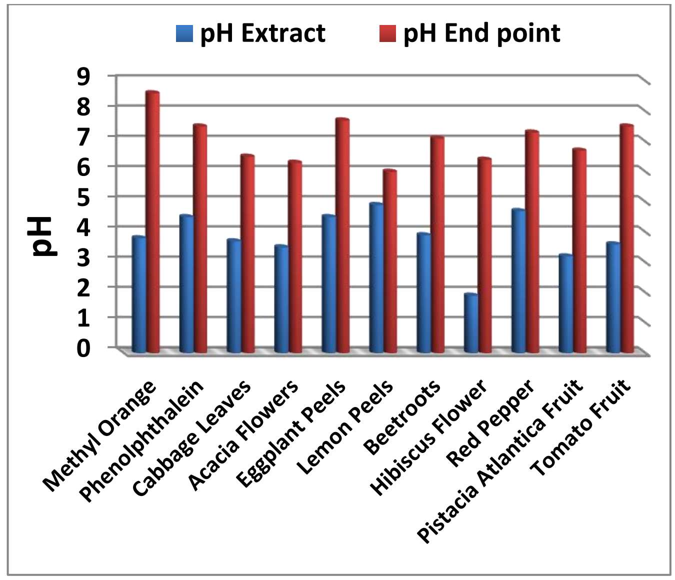


Figure 2: The change of the pH of extracts at the endpoint

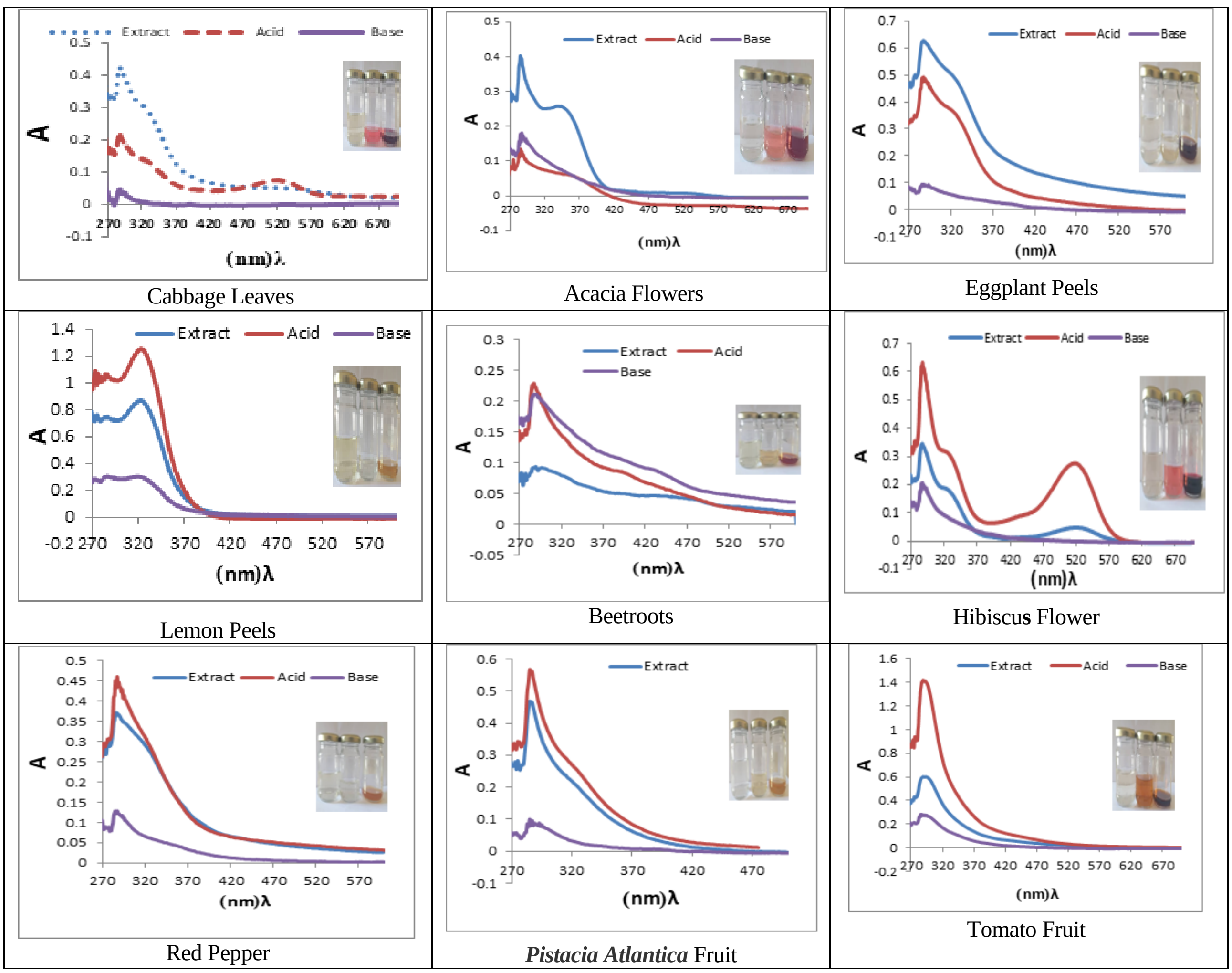


Figure 3: UV-vis spectra of plant extracts in acidic, neutral and basic media

An electronic spectrophotometer (Uv-Vis) was used to determine the absorbance of the extract in the visible region (ie. 200-900 nm) and the wavelength of maximum absorption (λ_{max}) extrapolated for each extract. The absorption was plotted against the wavelength. It was included in Table (2) and Figure 3, with an explanation of the colour of these extracts in each medium and its comparison with the absorption spectra of the pure extracts.

UV-Vis spectrophotometer analysis of cabbage leaf extract showed that the maximum wavelength at (λ_{max}) 519 nm is due to anthocyanins, which have an absorption in the region between 465-560 nm, which belongs the anthocyanin pigment that give red colour for its extract. The hibiscus extract has λ_{max} at 520 nm, as they have been known to contain anthocyanins [18-16]. As for the eggplant peel extract, it was absorbed in 285 nm wavelength and with an overlapping absorption at 320 nm, respectively, this absorption disappear in base medium as the colour is vanish after equivalent point.

Moreover, Figure 3 showed that the extract of Red Acacia flowers absorbs at a λ_{max} of 285 nm and at 330 nm, respectively. This absorption disappeared in the basal medium as the colour vanish.

The results also showed that lemon peel extract absorbs at a wavelength of 320 nm and this absorption was due to pigments strong. Tomato date extract absorbs only at a wavelength of 285 nm, and pepper extract absorbs at a wavelength of 285 nm which is similar to the spectrum of tomato, which attributed to the extract contains β-carotene.

However, beetroot extract absorbs at a wavelength of 285 nm and with an overlapping absorption in the range of 400-480 nm, respectively, this absorption belongs to a high content of betalain Betalain pigment. ***Pistacia Atlantica*** fruit seed extract absorbs at a wavelength of 285 nm and with an overlapping absorption at 320 nm, respectively.

4. Conclusion

In this research, dyes were successfully extracted from coloured plants, which could be used as chemical indices and as a guide for acid-base titrations. The behaviour of the coloured aqueous extracts was compared with standard indicator of phenolphetaline and methyl orange. The pH function of the pure aqueous extracts was measured and it was also measured at the equivalence point. The pH values of all aqueous extracts ranged between 1 - 4.5 before titration started, and their values after titration and at the equivalence point ranged between 6-7.7. UV-VIS spectra of pure aqueous extracts were recorded and their maximum wavelength was determined. The spectra were also recorded in both acid and base medium. The electronic spectra, which were slight differ from the electronic spectra of the pure extracts, indicated the extent of the consistency of these extracts, and their chemical composition change with the change in the acidity function. The obtained results confirmed the possibility of using natural endpoint indicator in chemical titration experiments to identify the break-even point, and thus it is considered safer than using synthetic chemical endpoint indicator.

5. Recommendations

It is advised to investigate the viability of applying these coloured plant extracts to various additional titrations, such as complex formation titrations, precipitation titrations, or other titrations.

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Declaration of Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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