

Comparative Analysis of Natural and Synthetic Indicators

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Abstract

Analytical reagents such as acid-base indicators are crucial for identifying the endpoint of neutralization reactions. Due to their unique colour shifts across specific pH levels, synthetic indicators like methyl orange and phenolphthalein are frequently employed in laboratories. However, the growing interest in green chemistry has led to an increased interest now in studying alternative indicators such as naturally occurring pigments found in plants. In the current study, we aimed to compare extracts of rose (*Rosa* spp.) and turmeric (*Curcuma longa* L). The extraction of rose petals and turmeric involved the use of an ethanol-water solvent system. Extracts were tested for their ability to respond color to different pH levels and their performance in acid-base titrations. In addition to other factors, the study considered endpoint visibility and reproducibility, as well as short-term stability and percentage deviation from reference indicator results. Additionally (i.e. Rose petals are rich in anthocyanin-type pigments, which change colour with pH, while turmeric contains curcuminoids, and curcumin specifically produces color under alkaline conditions.... The suitability of the plant extracts as natural acid and base indicators will be determined by analyzing experimental observations. The investigation proposes a straightforward, budget-friendly, and eco-friendly method for researching plant-based indicators and their potential utilization in everyday educational and analytical settings.

Keywords: Natural indicator: synthetic indicator: rose anthocyanin: turmeric: curcumin: acidbase Titration: pH: green chemistry

1. Introduction

Quantitative analysis of the concentration of acidic and basic substances involves titration between acids and bases. This technique is known as acid-base chemistry. The titration's endpoint is typically indicated by an acid-base indicator, which displays a noticeable color change over essentially the same pH transition period. Because of the well established transition behaviour, methyl orange and phenolphthalein are widely accepted indicators used in analytical aspiration and education. Typically, acid-base indicator pigments are in two or more forms with different hues. A noticeable color change is observed when the proportions of these forms are altered by changes in hydrogen-ion concentration. Hence, the usefulness of an indicator is dependent not only on colour change itself, but also on the position and sharpness at which it begins and ends relative to the equivalence-point pH. The field of green analytical chemistry has witnessed a surge in interest for natural indicators. Anthocyanins, curcuminoids, betalains and other naturally coloured compounds found in plant materials are all natural dyes. According to a recent review

in the Microchemical Journal, there is an increasing interest in using plant extracts as green indicators for acid-base titrimetric analysis. The study examined extraction, phytochemistry composition (including all its components), and spectroscopy and TIR methods with great attention to detail. Anthocyanin-type pigments are responsible for the distinctive colour of rose flowers, making them particularly fascinating. Past experiments have revealed that rose anthocyanin extracts display noticeable color. One reported study showed that the absorption peak varied significantly with pH, suggesting a sensitive pH of these pigments that had been extracted. [M]. Another natural source of pigment is Turmeric (*Curcuma longa* L.), which is easily accessible. Curcuminoids, particularly curcubin in particular, are associated primarily with its yellow colour. The structural features of turmeric undergo changes that are influenced by pH, leading to noticeable differences in color. In the Journal of Chemical Education, a study revealed that curcumin extract could be used as an acid-base indicator and demonstrated that RGB image analysis could track pH-related color changes. Additionally, The behaviour of natural pigments differs from that of conventional synthetic indicators. Colour stability and analytical performance are influenced by the extraction solvent, pigment concentration (sodium), plant variety, temperature, light, oxygen, and storage conditions. Recent reviews have highlighted the need for pigment stability and standardization when natural colourants are created as materials that react to pH. This is particularly noteworthy. The purpose of this study was to compare rose and turmeric extracts with methyl orange and phenolphthalein through controlled pH testing and acid-base titration experiments. This method is described below.

Nature's most famous ingredients are rose and turmeric, which have been used in various ways across cultures and culinary traditions. Rose, known for its delicate and comforting scent, is globally recognized, while turmeric is celebrated for promoting anti-inflammatory and antioxidant benefits. In holistic wellness and beauty rituals, they are frequently used as a classic synergistic pairing to promote healing, radiates, and balance.

A controlled pH test and acid-base titration experiments were conducted to compare rose and turmeric extracts with those of methyl orange and phenolphthalein.

1.1. Aim.

To compare the natural acid-base indicators of rose and turmeric extracts with those of synthetic ones.

1.2. Objectives.

- To manufacture indicator extracts derived from rose petals and turmeric.
- To scrutinize their hues in varying pH levels.
- To compare those of methyl orange and phenolphthalein.
- To ascertain their suitability for acid-base titrations.
- To appraise the degree of fidelity and briefness. To analyze the efficacy of plant indicators in green-chemistry contexts.

2. Materials and Methods

2.1. Chemicals and reagents.

The following chemicals were used-

Hydrochloric oxide (NaOH)

Acetic Acid (CH₃COOH) Ammo

Sodium nium hydroxide

Distilled water

Ethanol

Phenolphthalein

Methyl orange

The apparatus used-

Beakers

Conical Flasks

Test tubes

Measuring cylinder

Pipettes

Burette

Volumetric flasks

Funnel

Filter paper

Mortar and pestle

Analytical balance

PH meter or standard pH paper.

Those were hydrochloric acid, sodium hydroxide, acetic acid ($\text{Al}_2 + \text{HCl}$), ammonium hydroxide, and ethanol with distilled/deionized water. The colour-response study was conducted using standard buffer solutions that maintained the appropriate pH level. Synthetic indicators such as methyl orange and phenolphthalein were employed as reference markers. The standard laboratory procedures were used to prepare all solutions. Whenever quantitative titration is conducted, the standardized concentration of the sample should be recorded.

2.2. Plant material.

The rose petals, which were fresh and healthy, were gathered and gently washed with distilled water. Turmeric rhizomes or certified turmeric powder was utilized as the second plant element. In the laboratory notebook, the botanical name, source, collection date, and authentication information should be recorded and included in the final manuscript. All other details are noted.

2.3. Preparation of rose extract.

Method.

1. About 10 g of fresh rose petals were measured and stored.
2. The petals were treated with distilled water.
3. They were then sliced into tiny fragments and placed in a mortar.
4. Around 50 mL of ethanol and water solvent were added.
5. The material was macerated thoroughly.
6. The mix was left to sit for roughly 30-60 minutes, with erratic movements.
7. It was filtered into Whatman No. 1. The resulting filtrate was placed in an amber-colored container.
8. It was stored at around 4°C until it was analysed.

The acidic nature of alcoholic extraction can be explored due to the solvent composition, which affects the extraction of rose anthocyanins; some previous research has demonstrated the usefulness of extracting rose anion dyes using citric acid in methanolic conditions.

2.4. Preparation of turmeric extract.

Preparation of turmeric indicator.

1. The turmeric powder was weighed with precision at approximately 5 g.

2. It. The contents were transferred to a 100-mL conical flask.' Around 50 mL of ethanol and water solvent were added.
3. An hour and thirty minutes were allotted to shake the mixture.
4. For roughly 30 minutes, it was left to stand.
5. Whatman No was used to filter the mixture 1.
6. The yellow filtrate was gathered and kept in an amber bottle.'
7. The extract was utilized in subsequent pH and titration experiments.' Curcumin causes the yellow color of turmeric and changes its structure with pH, resulting in visible color changes, especially when it is in an alkaline solution.

2.5.Synthetic indicators.

References were made to commercial methyl orange and phenolphthalein. The use of the same approximation for the number of drops or equivalent units during each titration ensured that there was minimal variation in indicator quantity.

2.6.pH dependent color response

Standard solutions that covered pH 2, 4, 6, 7, 8, 10, and 12 were created or acquired through the use of buffer solutions. To test pH values, a 2 mL buffer solution was added to ice from sanitized test tubes. A corresponding amount of rose extract or turmeric extract was added separately. The colour was observed immediately. The same experiments were carried out on methyl orange and phenolphthalein. Each observation was replicated.

2.7.Acid–base titration study.

The indicator's performance was evaluated through titration experiments.

2.7.1. Strong acid–strong base titration.

A standardized form of HCl was transferred to a conical flask and tested against simulated NaOH. Separate titrations were performed using Rose extract; Turmeric extract; Methyl orange; Phenolphthalein. The endpoint was marked with a continuous change in colour. The process of making these determinations was repeated three times.

2.7.2. Weak acid–strong base titration.

By using four indicators, it was possible to compare a measured volume of standardized acetic acid with that of standard NaOH. The pH value was 6.4%.

2.7.3. Strong acid–weak base titration.

Titrating of HCl against standardized form (NH₄OH) with one of the four indicators where appropriate was observed. Comparing the endpoint volume, colour visibility, and reproducibility were compared to determining if each indicator was suitable.

2.8 Stability study of the sample used

The prepared natural indicators were stored under defined conditions and evaluated at predetermined intervals.

Colour, clarity and indicator response were recorded on days: 0, 3, 7, 14 and 30.



Fig: Analysis of natural and synthetic indicators

3. Result

3.1 Characteristics of plant extracts

Parameter	Rose extract	Turmeric extract
Plant material	Rose petals	Turmeric powder
Amount used	10g	5g
Extraction solvent	Ethanol- water	Ethanol- water
Solvent volume	50ml	50 ml
Extraction time	30min	30min
Initial colour	Reddish pink	Yellow
Extract pH	6.6	7.2
Extraction yield	17%	12%
Storage condition	Room temperature	Room temperature

3.2 pH-Dependent colour response

PH	Replicate 1	Replicate 2	Replicate 3	Final Colour
2	Dark pink	Dark pink	Dark pink	Dark pink
4	Pink- Red	Pink-Red	Pink-Red	Pink- Red
6	Pink- purple	Pink-purple	Pink-purple	Pink-Purple
7	Purple	Purple	Purple	Purple
8	Blue- Purple	Blue- Purple	Blue- Purple	Blue- purple
10	Greenish	Greenish	Greenish	Greenish
12	Brownish	Brownish	Brownish	Brownish

Colour response of turmeric extract

PH	Replicate 1	Replicate 2	Replicate 3	Final Colour
2	Yellow	Yellow	Yellow	Yellow
4	Yellow	Yellow	Yellow	Yellow
6	Yellow	Yellow	Yellow	Yellow
7	Yellow	Yellow	Yellow	Yellow
8	Yellow -orange	Yellow -orange	Yellow -orange	Yellow -orange
10	Reddish-brown	Reddish-brown	Reddish-brown	Reddish-brown
12	Brown	Brown	Brown	Brown

3.3 Synthetic indicator response

pH	Methyl orange	Phenolphthalein
2	Red	Colourless
4	Transition region	Colourless
6	Yellow	Colourless
7	Yellow	Colourless
8	Yellow	Transition region
10	Yellow	Pink
12	Yellow	Pink

3.4 Titration results

Table 1. HCL-NaOH titration

Indicator	Trail 1 (ml)	Trail 2 (ml)	Trail 3 (ml)
Methyl orange	24.9	25.0	25.1
Phenolphthalein	25.0	25.1	25.0
Rose	25.3	25.5	22.5
Turmeric	26.0	26.2	27.0

Table 2. CH₃COOH –NaOH titration

Indicator	Trail 1 (ml)	Trail 2 (ml)	Trail 3 (ml)
Methyl orange	25.0	24.8	24.9
Phenolphthalein	26.0	25.1	25.8

Rose	25.4	26.0	27.8
Turmeric	26.1	26.9	26.3

Discussion.

The purpose of this study was to assess the suitability of rose (*Rosa* spp.) and turmeric (*Curcuma longa* L.), as natural acid-base indicators, and to compare their performance with methyl orange and phenolphthalein. The comparison was based on the apparent color response at different pH levels, acid-base titration endpoint detection, reproducibility, and short-term stability. Additionally, these factors were considered. The presence of anthocyanin-type pigments was responsible for the varying pH levels in rose extract, which affected its colour response. Anthocyanins exhibit significant color differences due to their sensitivity to hydrogen-ion concentration and structural changes in response, particularly with pH fluctuations. The rose extract's colour change provides a straightforward way to visually distinguish changes in the acidity or alkaline balance of the test solution. Variations in colour change may be attributed to the type of rose, the pigment used for extraction, and the concentration of solvents used.

Changing pH was also observed in the turmeric extract. Turmeric contains curcuminoids, which are the primary coloured pigment in turmeric. The hue of turmeric can vary depending on the chemical reaction, and it displays a highly acidic-based response. The availability of natural indicator in the form of turmeric is convenient and easy. Earlier studies have shown that turmeric/curcumin extracts are useful for acid-base indicator purposes. See also: During the titration process, it is essential to investigate how the natural indicators perform. To ensure a consistent identification of the endpoint, illustrative indicators should provide pronounced color transitions near their equivalence points. As a result, the titration volumes obtained from rose and turmeric extracts were compared with those obtained using methyl orange and phenolphthalein. The endpoint volume obtained with a natural indicator would be slightly less than the reference indicator, indicating comparatively good end point agreement under the tested conditions. However, for some reason, this is not always true. Interpretation of results should consider the type of acid-base system under investigation.

A strong acid–strong base titration indicator may not be equally suitable for an effective endpoint. Analytical usefulness of the indicator depends on its relative position in relation to the equivalence-point pH (colour shift range).. Practical benefits are also derived from these natural indicators. Rose petals and turmeric are readily available plant materials that can be extracted with ease. They may be used to reduce reliance on commercially produced synthetic indicator solutions for some educational or preliminary analytical purposes.) The focus of recent research has been on exploring plant extracts as green indicators for acid-base titrimetric analysis. Even so, natural indicators have their limitations. *ibid*. The concentration of pigment and the intensity of the color in plant extracts can vary based on the source, age, extraction process, and storage conditions, as opposed to standardized commercial indicators. The variation in rose extract may be attributed to the differing anthocyanin pigment levels among different rose varieties. For a consistent output, it is essential to standardize the plant material, extraction solvent, duration of operation, and indicator concentration.

The stability of the extracted materials is another significant aspect. Pigments' natural color response can be influenced by exposure to light, temperature, and prolonged storage. Hence, it is important to take into account the stability observations made during this examination when determining the practical usefulness of the extracts. Reproducibility is a prerequisite for analytical applications. Repetition of the titrations can result in closely agreeing endpoint volumes, which makes the natural indicator more consistent under

experimental conditions. By analyzing the mean and standard deviation of both replicate titrations, one can quantitatively determine this reproducibility. In summary, the current comparison demonstrates that pigments derived from plants can provide quantifiable visual responses to changes in acidity and alkalinity. Despite not being the sole synthetic indicator substitute, rose and turmeric can be considered as cost-effective and readily accessible replacements for specific acid-base applications. The suitability of each natural indicator depends on its colour-transition behaviour, endpoint agreement (i.e, stability), reproducibility, and sensitivity. These discoveries lend credence to the wider utilization of natural plant pigments in green analytical chemistry, particularly when streamlined visual detection is necessary and highly standardized commercial indicator systems are not required. The reliability and analytical applicability of these natural indicators could be improved through further work on optimizing extraction conditions, standardizing pigment concentration, testing with a greater number of independent plant samples.

5. Comparative evaluation

Table. Comparative evaluation framework

Parameters	Rose	Turmeric	Methyl orange	Phenolphthalein
Source	Plant	Plant	Synthetic indicator	Synthetic indicator
Principle colourant	Anthocynin-type pigments	Curuminoids	Azo dye	Phthalein dye
PH response	6.6	7.2	4.4	8.2
Colour transition	Dark pink - brownish	Yellow - brown	Red – orange – yellow	Colourless – pink
Strong acid/strong base	24.43	26.40	25.00	25.03
Weak acid – strong base	26.40	26.43	25.23	25.03
Endpoint visibility	Red pink to greenish brown	Yellow to brown	Red to yellow	Colourless to pink
Reproducibility	Lower	Moderate	High	High
Short-term stability	Sensitive to light, temperature and pigment	Depends on storage	Generally stable	Generally stable
Preparation requirement	Extract preparation	Extract preparation	Commercial	Commercial
Renewable plant source	Yes	Yes	No	No

Conclusion.

This study makes a systematic comparison of two plant-derived indicators, rose and turmeric, against the more widely recognized synthetic indicators (both described as methyl orange and phenolphthalein). Using basic extraction techniques, one can investigate rose and turmeric extracts by conducting pH-based

colour tests and acid-base titration experiments. Most of the compounds found in rose pigments are anthocyanin-based, but curcuminoids, such as turmeric, contribute to turmeric's unique color response based on its pH. The appropriateness of natural indicators should be determined by the experimental pH-response range, titration endpoint, reproducibility, percentage deviation, and storage stability. The findings will demonstrate the acid and cationic acid systems that can be utilized for endpoint detection. The investigation demonstrates a practical method for studying renewable plant materials as acid-base markers and presents an accessible experimental model for green analytical chemistry. However, variation in plant material and extract composition requires proper standardization of natural indicators for routine quantitative analytical applications.

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