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# Utilization of Waste Red Onion (*Allium cepa L.*) Peels as Natural Acid-Base Indicator

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**Abstract**

This study addresses the growing demand for sustainable analytical practices by evaluating the potential of ethanolic extract of waste red onion (*Allium cepa L.*) peels as a bio-indicator for acid-base titration in volumetric analysis. The extract was prepared through maceration in ethanol and characterized using phytochemical screening, UV-Vis, and FTIR spectroscopy. Its performance was assessed in strong acid-strong base titration and compared with conventional synthetic indicators, methyl orange, phenolphthalein, methyl red and bromothymol blue. Statistical analysis using one-way ANOVA revealed significant difference ($p < 0.05$) between the titre values obtained with the red onion peel extract and the synthetic indicators. However, Tukey Pairwise comparisons confirmed no significant difference between methyl orange, methyl red, bromothymol blue and red onion peels extract except phenolphthalein. These findings suggest that the red onion peel extract is a promising, eco-friendly, and effective alternative to synthetic indicators in strong acid-base titration, with potential applications in sustainable analytical practices.

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## Introduction

The global drive toward sustainable and green chemistry has significantly accelerated the search for eco-friendly alternatives in chemical analysis especially in volumetric titration (Singh and Singh, 2015). However, synthetic acid- base indicators commonly used during titration are often associated with high cost, toxicity and environmental pollution (Kapilraj *et al.*., 2019). Consequently, researchers have increasingly turned to natural alternatives that are cost effective, readily available and environmentally friendly. One potential approach involves the valorization of agricultural waste materials which simultaneously reduces disposal issues and provides useful, cost effective resources for scientific application. Red onion (*Allium cepa* L.) peels, typically discarded as agricultural wastes are rich in flavonoids, anthocyanins and other pigments capable of changing colour across different pH values (Gupta *et al*., 2024; Kumar *et al*., 2022; Xue *et a*l., 2024). This colour changing property render them a promising substitute for synthetic indicators (Patil *et al*., 2020; Pandit *et al*., 2023). Beyond their potential use as indicators, waste onion peels have been applied in organic fertilizer (Zhang *et al*., 2024), in food processing industry as sources of dietary fiber and bioactive compounds (Benítez *et al*., 2011), antioxidant and antimicrobial agent (Joković *et al*., 2024), as well as sources of renewable energy (Segundo *et al*., 2022).

Several studies have demonstrated natural plant extracts as effective acid-base indicator such as red bulbs of Allium cepa (Jebson and Moses, 2015), Ipomoea and Caesalpinia flowers (Muhammad *et al*., 2016), *Syzygium cumini* (L.) Skeels (Zulfajri, 2018), *Acanthus sennii* chiovenda flowers (Baye and Leshe, 2019), *Rosella Calyces Hibiscus Sabdariffa* (Genevieve *et al*., 2020), *Clitoria ternatea* L. (Fitri and Fikroh, 2021), juice of *Allamanda blanchetii* flower (Swapna *et al*., 2021), Rose flower (Olanrewaju and Adeosun, 2023), and 97% ethanolic extract of coffee pericarp (Nazziwa, 2023).

Sustainable analytical practices are vital in green analytical chemistry, as they minimize hazardous waste, reduce energy consumption and toxic reagents thereby protecting both the environment from pollution and public health from chemical exposures (Kannaiah and Chanduluru, 2023; Miladinović, 2025). Synthetic Indicators can cause serious health problems, such as birth defects, cancer, allergic reactions and high risk of brain and thyroid tumors. As a result of these risks, their harmful effects are becoming more concerning. In comparison, bio-indicator are generally more safe with few or no side

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effects, they are biodegradable and more environmental friendly (Ghaisas and Masali, 2020). Therefore, this study highlights the importance in promoting more ecofriendly and analytical methods.

Despite extensive research on the use of plant extracts as acid-base indicators, systematic investigations focusing on discarded red onion peels with minimal economic value rather than edible bulbs remain limited and many reported studies lack comprehensive statistical validation and spectroscopic characterization of the extract. Therefore, the present study aims to evaluate the feasibility of ethanolic extract of waste red onion peels as acid-base bio-indicator for sustainable volumetric analysis. Specifically, this work seeks to: (i) prepare and characterize the extract using phytochemical screening, FTIR, UV-Vis spectroscopy. (ii) assess its performance in strong acid versus strong base titrations in comparison with selected synthetic Indicators, and (iii) statistically analyze the titration data to validate its sustainability as an eco-friendly alternative in analytical chemistry.

**Materials And Methods**

**Reagents and Apparatus**: All reagents used in this study were of analytical grade and used without further purification. Methyl orange, phenolphthalein, methyl red and bromothymol blue from BDH while hydrochloric acid (98% purity), Sodium hydroxide (98% purity), and ethanol (99.0% purity) from Sigma Aldrich, through the Department of Science Laboratory Technology, Daura, Katsina, State and distilled water was used for the

**Preparation of Required Reagents.**

**Sample Collection and Preparation**: The red onion peels were obtained from a vendor at central market in Daura, Katsina State, Nigeria in the month of April, 2025.

The red onion peels were placed in clean plastic polyethene bag and taken to the laboratory. All unwanted particles were removed, rinsed quickly to avoid excessive loss pigment and dried at room temperature for 2 days. Then the sample was grinded into fine powder using blender.

Figure 1.0: Dry Red Onion Peels Waste

**Extraction of the Pigment and pH of the Extract:** The extraction of red onion peel was adopted from the method described by Adu and Gelyaman (2023), with few modifications. The extract was prepared by mixing 100g of the powder in 250cm$^3$, 97% ethanol and filtered using Whatman filter paper after 24 hours of maceration. The filtrate was then concentrated on hot plate at 40°C and kept in dark. The pH extract was measured using a calibrated pH meter.

**Phytochemical Properties:** The ethanolic extract of red onion peels was filtered using Whatman filter paper for phytochemical analysis to determine the presence of flavonoids and anthocyanins. The presence of flavonoids were evaluated using alkaline test (Verma *et al*., 2018; Sukumar *et al*., 2020), shinoda's, ferric chloride, zinc chloride and ammonia test (Sukumar *et al*., 2020). Anthocyanins were identified by adding 2 cm$^3$ of 2M HCl to 2cm$^3$ of the extract in test tube resulting in a pink-red colouration which changed to purplish blue upon the addition of ammonia solution (Obouayeba *et al*., 2015).

International Journal of Basic Science and Technology
March, Volume 12, Number 1, Pages 1 - 9 http://www.ijbst.fuotuoke.edu.ng/ 3
https://doi.org/10.5281/zenodo.18859547 ISSN 2488-86

**UV- Vis Spectroscopy Analysis:** The method reported by Baye and Leshe (2019) was adopted to determine the electronic absorption spectra of ethanolic red onion peel extracts using UV-Vis spectrometer scanned from 400-700nm. The extract was diluted 10-fold with the same solvent and 5cm$^3$ of the diluted extract was placed in 1cm path length quartz cuvette. Pure ethanol was used as blank for baseline correction.

**FT-IR Spectroscopy Analysis**: The FT-IR analysis was performed on the ethanolic extract of red onion peels to identify the functional groups. A drop of the liquid extract was mixed thoroughly with dry potassium bromide (KBr) powder to obtained homogeneous mixture, then compressed under pressure to form a thin transparent disc. The KBr plates were then secured in the spectrometer's sample holder. Spectra were recorded in the absorbance mode over the range of 400 to 4000 cm$^{-1}$, this method was adopted from Jain *et al*., (2016).

**Titration Using the Extract and Selected Synthetic Indicators**: The extract was tested with acid and base solutions, and the average titre values were recorded as shown in the Table 1.0. Three drops the extract were added into 25cm$^3$ of 0.1M NaOH in conical flask and titrated against 0.1M HCl solution in the burette until first permanent colour change was observed. The procedure was repeated three times. The same method was repeated with selected synthetic acid-base indicators, i.e, methyl orange and phenolphthalein. This method was adopted from Jebson and Moses (2015).

**Statistical Analysis of Data:** The experimental data obtained from triplicate titration of strong acid (HCl) against strong base (NaOH) using methyl orange (MthOr), phenolphthalein (Phpth), methyl red (Mtred), Bromothymol blue (Brblue) and ethanolic red onion peels extract (Ropex) were analyzed by one-way ANOVA using Minitab 17 statistical software as shown in Table 4.0. The analysis highly significant differences among the means $p < 0.001$.
Tukey Pairwise Comparisons (Table 5.0) confirmed no significant difference between methyl orange, methyl red, bromothymol blue and red onion peels extract while phenolphthalein (group C) is significantly different. The identical standard deviations across indicators indicate equivalent precision in endpoint detection.

## Results and Discussion

The outer dry skin and epidermal layers of red onions contain anthocyanins and phenolics (Constantine and Istrati, 2022). Various methods have been reported for anthocyanins extraction from red onion peels, including reflux, maceration, percolation and soxhlet extraction (Tena and Asuero, 2022; Constantine and Istrati, 2022). In this work, maceration was selected for its effectiveness, low operating temperature, reduced solvent consumption, and prolonged solute-solvent interaction.
Saptarini and Herawati (2018), reported that extraction via maceration and reflux method yield higherquantities than percolation and soxhlet extraction.
Extraction efficiency and anthocyanin stability are also influenced by solvent choice and pH of solution. Ali *et al*. (2016), reported higher yields from red onion peels using ethanol / 0.01% HCl compared to methanol / 0.01% HCl. Natural anthocyanins exhibit greater stability at lower pH values, such as 2.0 and 3.0 (Xue *et al*., 202). In this study, 97% ethanol served as the solvent, resulting in an extract pH of 6.5.

### Phytochemical Properties

The phytochemical screening of the ethanolic extract of red onion peels aimed at detecting the presence of flavonoids and anthocyanins were presented in Table 1.0.

Table 1.0 : Results of Phytochemical Screening of Ethanolic Extract of Red Onion Peels

| Test | Observation | Ethanolic Extract | Inference |
|---|---|---|---|
| Alkaline test | Yellow | + | Flavonoids |
| Shinoda's test | Red | + | Flavonoids |
| Ferric chloride test | Greenish brown | + | Flavonoids |
| Zinc chloride test | Magenta | + | Flavonoids |
| Ammonia test | Yellow | + | Flavonoids |
| Hydrochloric acid test | Purple | + | Anthocyanins |

**International Journal of Basic Science and Technology**
March, Volume 12, Number 1, Pages 1 - **9** http://www.ijbst.fuotuoke.edu.ng/ 4
**https://doi.org/10.5281/zenodo.18859547** **ISSN 2488-86**

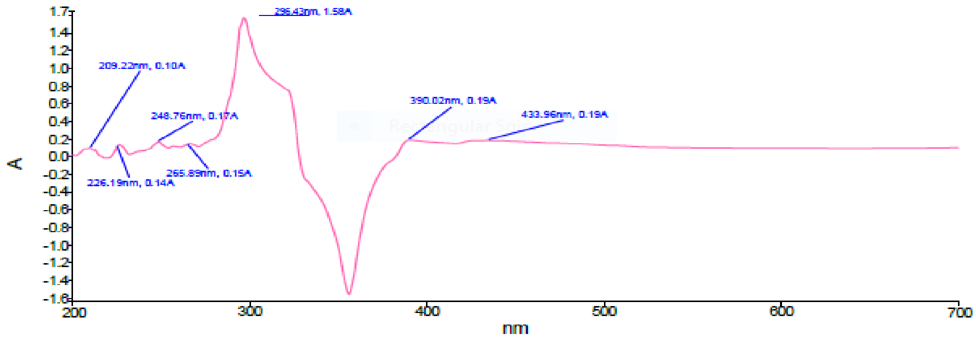


Figure 2.0: UV- Vis Absorption of the Ethanolic Extract of Red Onion Peel

All tests yield positive results (+), indicating abundant flavonoids and anthocyanins in the extract. These findings agree with the previous reported by Obouayeba *et al.* (2015); Verma *et al*. (2018); and Sukumar *et al*. (2020). The presence of anthocyanin in the red onion peels extract, detected in this study during phytochemical screening is responsible for its acid-base indicator properties. Anthocyanins are non-toxic flavonoids found in plants, soluble in water and alcohol (Kossyvaki et al., 2025), which makes them suitable for safe and effective use as natural pH indicators. A representative structure of this compound (Figure 3.0) as well as its role in the colour changes observed at different pH levels (Mir et al., 2025).

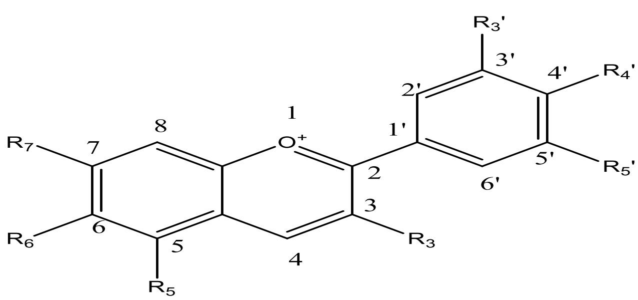


Figure 3.0: Structure of Anthocyanin (Wahyuningsih *et al*., 2017; Baye and Leshe, 2019).

All tests yield positive results (+), indicating abundant flavonoids and anthocyanins in the extract. These findings agree with the previous reported by Obouayeba *et al.* (2015); Verma *et al*. (2018); and Sukumar *et al*. (2020).

**UV- Vis Absorption of the Extract**

The absorption spectra of the extracted onion peel were measured using a UV- Vis spectrophotometer over a wavelength range of 200-700nm, as shown in Figure 2.0. A maximum absorption peak at 296.34nm was obtained, closely matching values of 300-380nm reported by Puiso *et al*. (2023) for water-extract and attributed to flavonoids such as flavonols and anthocyanins in red onion peels, 486nm using only water (Aduloju and Shitta, 2021), while extract of acidified and unacidified water showed maxima around 507nm (Adu and Gelyaman, 2023). These variations in absorption peaks arise from differences in the quantity of functional groups and color characteristics of the extracted anthocyanins.

**FT-IR Spectroscopy Analysis**

Based on the FTIR analysis in Figure 3.0, the absorption peak at 3332 $cm^{-1}$ corresponds to the - OH stretching vibration (phenolic, broadened by residual ethanol used in extraction, aromatic C=C stretching at 1647 $cm^{-1}$, aromatic C-H bending at 1416cm-1, and C-O stretching at 1088$cm^{-1}$ confirming the presence of anthocyanins. These findings align with those reported by Adu and Gelyaman (2023) and Obuebite *et al*. (2023).

March, Volume 12, Number 1, Pages 1 - **9** http://www.ijbst.fuotuoke.edu.ng/ 5
https://doi.org/10.5281/zenodo.18859547 ISSN 2488-86

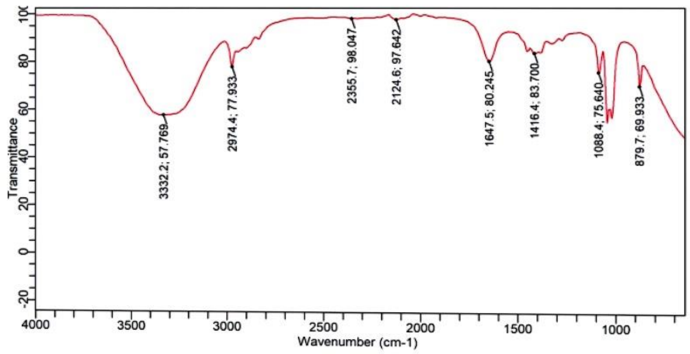


Figure 4.0: FT-IR Spectrum of the Ethanolic Extract of Red Onion Peels

**Titration Results of Selected Synthetic Indicators and the Extract**

Titration experiments compared the performance of synthetic Indicators (methyl orange and phenolphthalein) with red onion peel extract in standardizing HCl and NaOH solutions. Triplicate measurements of titre values in $cm^3$ were recorded as shown in Table 3.0. The red onion peels extract titre(14.80 ± 0.10 $cm^3$) was closet to that of methyl orange (14.90 ± 0.10 $cm^3$) , therefore it is viable natural substitute for methyl orange in strong acid base titration due to their closest titres compared to that of phenolphthalein (14.20 ± 0.10 $cm^3$). This findings align with titre values reported by Jebson and Moses (2015); red onion bulb extract (16.83 ± 0.01 $cm^3$), methyl orange (16.53 ± 0.05 $cm^3$), and phenolphthalein (16.23 ± 0.05 $cm^3$). This difference in titre values could be attributed to different concentration of the acid, base or the nature of deionized water used.

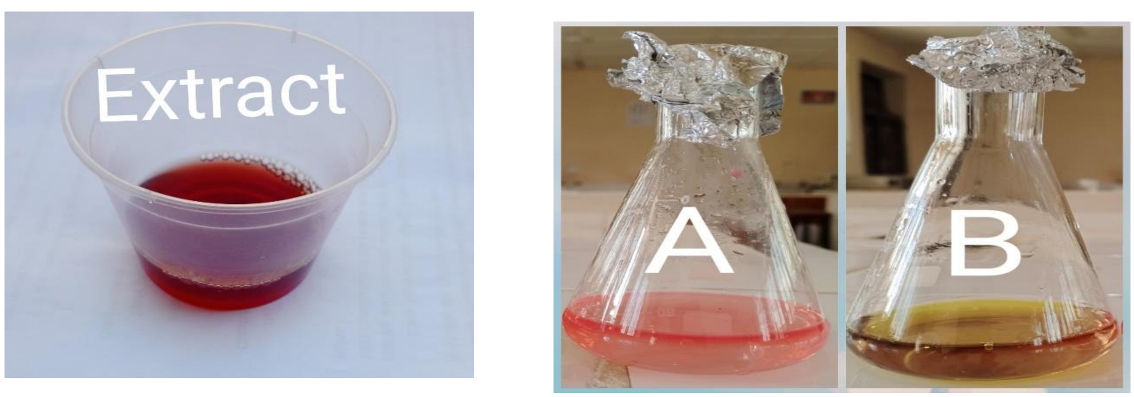


Figure 5.0: **E**thanolic extract of red onion peels, Colour Changes in acidic solution (A) and basic solutions (B)

Table 2.0**:** Titre Values ($cm^3$) Using Synthetic Indicators and Red Onion Peel Extract

| Indicators | 1st Experiment | 2nd Experiment | 3rd Experiment | Colour at Endpoint |
|---|---|---|---|---|
| Methyl orange | 14.90 | 14.80 | 14.80 | Pink |
| Phenolphthalein | 14.30 | 14.10 | 14.20 | Purple |
| Red onion peels extract | 14.80 | 14.90 | 14.70 | Colourless |
| Bromothymol blue | 14.70 | 14.60 | 14.70 | Yellow to Blue |
| Methyl red | 14.60 | 14.50 | 14.50 | Red to Orange |

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**Table 3.0:** Analysis of Variance

| Source | DF | Adj SS | Ad MS | F- Value | P - Value |
|---|---|---|---|---|---|
| Factor | 4 | 0.78933 | 0.197333 | 32.89 | 0.000 |
| Error | 10 | 0.06000 | 0.006000 | | |
| Total | 14 | 0.84933 | | | |

**Table 4.0:** Grouping Information Using the Tukey Method and 95% Confidence

| Factor | N | Mean | Grouping | S.D |
|---|---|---|---|---|
| MthOr | 3 | 14.8333 | A | 0.1000 |
| Ropex | 3 | 14.8000 | A | 0.1000 |
| Brblue | 3 | 14.6667 | AB | 0.0577 |
| Mtred | 3 | 14.5333 | B | 0.0577 |
| Phpth | 3 | 14.2000 | C | 0.1000 |

## Conclusion

In conclusion, this study demonstrates that the ethanolic extract of red onion peels is an effective, reliable, and ecofriendly substitute for methyl orange, methyl red and bromothymol blue in strong acid-base titrations. The statistical equivalence of the titre values confirms its accuracy while its preparation from agricultural waste offers significant advantages in terms of low cost, readily availability, simple to prepare, and environmental friendliness. This research successfully validates the conversion of red onion peels into a valuable analytical reagent, promoting sustainable chemistry practices as well as green analytical chemistry.

## Recommendations

**1.** Further research could explore the stability of the red onion peels extract over period of time as this would be important in its real life application.
2. It is recommended that the extract of red onion peels as indicator can be applied in teaching strong acid-base titration in schools.
3. The indicator properties of the extract can also be tested on acid-base titration involving strong acid versus weak base and weak acid versus strong base.
4. The study recommends the test for colour changes across pH 1-14.
5. Also, the residue after filtration of extract can also be tested in adsorption of heavy metals from aqueous solution.

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March, Volume 12, Number 1, Pages 1 - **9** http://www.ijbst.fuotuoke.edu.ng/ 8
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