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Developing Herbal Acid-Base Indicators from Pomegranate Seeds

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Abstract: *Natural indicators derived from plant sources offer an eco-friendly and cost-effective alternative to synthetic acid-base indicators. This study explores the potential of pomegranate (Punicagranatum) seed extract as a natural pH indicator. The extract was prepared using aqueous and ethanol-based solvents and tested against standard acidic and basic solutions to evaluate its color transition range. The results demonstrated distinct and reproducible color changes across varying pH levels, indicating the presence of anthocyanins and other flavonoids responsible for pH sensitivity. The study highlights the efficacy of pomegranate seed extract as a viable natural indicator, promoting sustainable and non-toxic alternatives for laboratory and industrial applications.*

Keywords: Pomegranate seeds, natural indicators, acid-base titration, anthocyanins, eco-friendly chemistry, pH sensitivity, sustainable alternatives

I. INTRODUCTION

Pomegranate (*Punicagranatum* L.), a member of the family Punicaceae, is a deciduous shrub or small tree with a longstanding history of cultivation in China. The first documented medicinal use of various pomegranate parts, including the peel, seeds, flowers, leaves, and roots, dates back to the Han Dynasty, as recorded in Min-Yi-Bie-Lu (Han Dynasty). Therefore, pomegranate has a very long history of use not only in traditional Chinese medicine but also in diverse clinical practices among Tibetans, Uyghurs, Miaos, and other ethnic groups. Apart from its nutritional significance, pomegranate has important medicinal attributes. Research indicates that different components of the pomegranate, such as the juice, pericarp, seeds, flowers, leaves, and peels, are rich in biologically active compounds with anti-diabetic, anti-tumor, anti-inflammatory, anti-malarial, and anti-fibrotic properties, which are widely recognized and utilized globally (Maphetu et al., 2022; Yisimayili and Chao, 2022). Moreover, studies have revealed that the bark of the pomegranate tree is a natural green corrosion inhibitor (Marsoul et al., 2020).

Several studies have highlighted the efficacy of anthocyanin-based indicators in accurately determining pH levels in various solutions. Compared to synthetic indicators, which often require complex synthesis and purification processes, plant-based indicators like pomegranate extract offer a more environmentally friendly alternative. The use of pomegranate seed extract as an acid-base indicator presents a sustainable alternative with significant potential for replacing conventional synthetic indicators in various analytical procedures. Moreover, its application in educational laboratories can promote the adoption of eco-friendly practices among students and researchers.

II. NATURAL ACID-BASE INDICATORS

Numerous studies have explored plant-based acid-base indicators, primarily from flowers, fruits, and leaves. Research has demonstrated that extracts from hibiscus petals, beetroot, red cabbage, and turmeric exhibit distinct color changes across a pH range (Chandran et al., 2018). These indicators have been compared to synthetic indicators and shown promising results in terms of accuracy and reproducibility (Patel & Sharma, 2020).

Studies by Rahman et al. (2021) and Singh & Mehta (2019) indicate that plant-based indicators, particularly those containing anthocyanins, can be a viable alternative to synthetic indicators. Their studies found that extracts from butterfly pea flowers, rose petals, and blackberries exhibit similar pH-dependent color changes, reinforcing the potential of anthocyanins in acid-base titrations.

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III. PHYTOCHEMICAL COMPOSITION OF POMEGRANATE

Pomegranate seeds contain anthocyanins, flavonoids, and tannins, which contribute to their pH-sensitive color-changing properties. Studies suggest that anthocyanins, a type of flavonoid, exhibit structural changes in acidic and basic conditions, leading to visible color shifts (Martínez et al., 2019). This property makes pomegranate seed extract a suitable candidate for an acid-base indicator.

Additional research by Banerjee et al. (2020) emphasizes the stability of anthocyanins derived from pomegranate. Their study focused on the extraction and stabilization of anthocyanins for use in food chemistry and analytical chemistry, further supporting the viability of pomegranate as a pH indicator.

Research by Gupta et al. (2021) demonstrated that pomegranate peel and seed extracts could effectively indicate pH changes in acid-base titrations. Their study compared the color variations of pomegranate extract against conventional indicators and found a high degree of accuracy in strong acid-strong base and weak acid-strong base titrations. Similarly, studies on other fruit-based indicators, such as grape skin extract, have confirmed their potential use in analytical chemistry (Das et al., 2017).

A study by Sharma & Kapoor (2022) explored the long-term stability of pomegranate extract as an acid-base indicator and its effectiveness in titrations involving weak acids and bases. Their results showed that pomegranate extract provided clear and distinguishable color transitions comparable to synthetic indicators.

The pomegranate seed, which is often discarded after the fruit is consumed, is a valuable source of these anthocyanins, making its use not only a sustainable alternative but also a potential solution to agricultural waste (Chaudhary et al., 2021). The process of extracting anthocyanins from the seeds involves simple extraction techniques, which are both cost-effective and environmentally friendly. This approach has the potential to offer a renewable, locally sourced, and biodegradable alternative to synthetic pH indicators, which are typically petroleum-based (Koch et al., 2018).

Pomegranate-based pH indicators could be especially valuable in educational settings, where they can serve as a hands-on, visual tool for students learning about acid-base chemistry. Additionally, their natural, non-toxic composition makes them suitable for a variety of other applications, including quality control in industries such as food processing and environmental monitoring, where the need for sustainable practices is rising (Saha& Banerjee, 2017).

In exploring the development of a herbal acid-base indicator from pomegranate seeds, several factors need to be considered. These include the extraction efficiency of anthocyanins from the seeds, the stability of the pigment in different environmental conditions, and the consistency of the color change across a wide pH range (Baskar et al., 2020). By addressing these challenges, the pomegranate seed extract could be developed into a reliable and scalable natural indicator.

Ultimately, the development of a herbal acid-base indicator from pomegranate seeds holds significant promise, not just as a scientific tool, but also as a step toward a more sustainable, eco-conscious approach to chemical analysis. By harnessing the natural chemical properties of pomegranate seeds, it is possible to create an alternative that is both effective and aligned with the growing global movement toward sustainability (Pandey et al., 2022).

IV. RESEARCH METHODOLOGY

Analytical-grade reagents, including hydrochloric acid (HCl), sodium hydroxide (NaOH), acetic acid (CH_3COOH), ammonia (NH_3), phenolphthalein, and methyl red, were procured from Mine Chemical, Mumbai. Reagents and volumetric solutions were prepared according to Vogel's methodology.Fresh fruits were purchased from a supermarket in Raigad and authenticated by the Botanical Department. The fruits were thoroughly cleaned, cut into small pieces, and 100 g of these pieces were macerated with 150 mL of a solution containing nine parts methanol and one part dilute hydrochloric acid for three hours. The extract was stored in a tightly sealed container, protected from direct sunlight.

The experiment was conducted using the same set of glassware for all titrations. Reagents were not calibrated, as identical aliquots were used for both titrations—one with a standard indicator and the other with the fruit extract. A total of 5 mL of titrant and three drops of indicator were used per titration. Each titration was performed five times, and the results were recorded. The mean and standard deviation were calculated from the obtained data.The methanolic extract of fresh Punicagranatum fruit was evaluated as a potential acid-base indicator. The results of this screening were compared with those obtained using standard indicators to assess its effectiveness.

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The fruit was screened for its use as an indicator in acid base titration and the results were compared with the results obtained by standard indicators methyl red, phenolphthalein. The results of the screening for strong acid- strong base (HCl&NaOH) , strong acid -weak base (HCl& NH3) , weak acid-strong base (CH_3COOH &NaOH) and weak acid-weak base(CH_3COOH & NH_3) are listed in Table acid (CH_3COOH), ammonia (NH_3), phenolphthalein, and methyl red, were procured from Mine Chemical, Mumbai. Reagents and volumetric solutions were prepared according to Vogel's methodology.

Titrant	**Titrand**	**Indicator &Color Change (pH Range)**	
		Standard	**Fruit Extract**
HCl	**NaOH**	Colorless to pink (PH)	Pink to colorless
HCl	**NH_3**	Red to yellow (MR)	Pink to colorless
CH_3COOH	**NaOH**	Colorless to pink (PH)	Pink to colorless
CH_3COOH	**NH_3**	Yellow to red (PR)	Pink to colorless

V. RESULTS AND DISCUSSION

Strength (M)	HClvsNaOH	HClvs NH_3	CH_3COOH vsNaOH	CH_3COOH vs NH_3
	PH	FE	PH	FE
0.1 M	7.8 ± 0.20	7.7 ± 0.24	7.4 ± 0.20	7.5 ± 0.62
0.5 M	8.0 ± 0.40	7.9 ± 0.32	7.8 ± 0.24	7.7 ± 0.34
1.0 M	10.2 ± 0.30	10.0 ± 0.34	9.5 ± 0.30	9.4 ± 0.36

VI. CONCLUSION

The results obtained in all the types of acid base titrations lead us to conclude that it was due the presence of flavonoids sharp colour changes, which occurred at end point of titrations. At the end point of it states that PunicaGranatum fruit extract as an indicator in all types of acid base titrations because of its economic, simple, accurate and precise.

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