

Evaluation of Improvised and Eco-Friendly Natural pH-Paper Indicators

Mussarat Jabeen^{1*}, Kainat Tariq¹, Atiya Rehman¹, Noreen Aslam¹, Ansa M. Zafar¹ and Syed Ubaid Hassain²

¹Department of Chemistry, Government Sadiq College Women University Bahawalpur, Bahawalpur, Pakistan

²Department of Chemistry, The Islamia University of Bahawalpur, Bahawalpur, Pakistan

*Corresponding email: dr.mussaratjabeen@gmail.com

Abstract:

A substance that changes color when pH changes is referred to as an indicator. Synthetic indicators, which are expensive and toxic, are currently the best option for estimating acid-base concentrations or hydronium and hydroxide ion concentrations. This study aims to prepare pH paper indicators from natural sources to overcome this problem. Indicator strips of this type are eco-friendly, cheap, durable, non-toxic, biodegradable, and easy to prepare even at home. In this application, we are using natural sources such as turmeric (*Curcuma longa*), rose (*Rosa Indica*), beetroot (*Beta vulgaris*), and red cabbage (*Brassica oleracea*) for the preparation of pH paper indicator strips. We used 73 acids, bases, and neutrals solutions to conduct comparative studies. These include fifty-nine household chemicals, such as milk, lemon, mango, honey, glycine, etc., and fourteen standard solutions of acids and bases of pH from 1 to 14. By dipping yellow-colored turmeric acidic paper into sodium hydroxide, we transform yellow-colored turmeric acidic paper into red-colored turmeric basic paper. The results are the same in both cases, i.e., turns yellow in acids and red in bases but unaffected in neutrals. Rose paper easily differentiates acids and bases while red cabbage gives almost the same results as pH paper (wide color change from red to dark blue). As these can be easily prepared and give comparable results with commonly used paper indicators, it would be possible to replace synthetic paper indicators.

Keywords: Turmeric, Rose, Beetroot, Red cabbage, Eco-friendly

1. Introduction

The COVID-19 pandemic is a totally individual, unique and distinctive experience that is an unrivaled worldwide phenomenon with inclusive and widespread repercussions (Haleem, Javaid, Vaishya, & Deshmukh, 2020; Verschuur, Koks, & Hall, 2021). Most of the countries have been shredded economically by the prolongation of the pandemic which is severely affecting higher education (Mishra, Gupta, & Shree, 2020; Rashid & Yadav, 2020). The entire education rate is going to decrease as the families are disheartened due to financial consumption on education. In this predicament, there is a requisite for a low-cost learning technique that is commodious in social distancing in COVID-19 (Dennis, 2020; Saggiomo & Velders, 2021). A purposeful way to understand chemistry is through experiments than studying course books as it creates curiosity and helps learners to perceive fundamental knowledge (Caraballo, Saleh Medina, Gomez, Vensaus, & Hamer, 2021). A few decades ago, it was supposed that you are not a terrorist or drug maker if you had a home laboratory, but you are an inventor and have the pursuit of knowledge (Saggiomo & Velders, 2021). During the COVID-19 pandemic, an eco-friendly and safe home-laboratory program was implemented in many institutes. The main aim of these home laboratories was to utilize household

items and study basic concepts of chemistry by designing some activities like pH, titrimetric, solubility, crystallization, phase equilibrium, purification and many more (Andrews et al., 2020). Indicators are tints or dyes that can be acquired from various plants, algae and fungi (Okoduwa, Mbora, Adu, & Adeyi, 2015). Flowers or plants that are pink, purple, blue or red coloured contain anthocyanin and can be used as indicators due to color changes with pH (Bhise, Shinde, Surve, Pimpodkar, & Shikalgar, 2014; Ghatage, Killedar, Hajare, & Joshi, 2017). pH indicators also known as acid-base indicators or neutralization indicators, are the reagents used to distinguish the acidic, basic and neutral characteristics of any substance and find out the endpoint in the titration process (Bhuvaneshwari, Sivaelango, Parthiban, Arun, & Kumaravel, 2015; Vadivel & Chipkar, 2016).

Most of the indicators used now a day are man-made synthetic indicators or organic compounds such as pH paper, litmus paper, phenolphthalein, thymol blue, methyl red, methyl orange, methyl yellow, bromophenol blue, pentamethoxy red, azo violet, and many more (Barbosa, 2005; Hanson, 2018; Pietrzyk & Frank, 1979; Thomas & Brogat, 2017) prepared in laboratories and used to determine pH of any substance. These synthetic indicators are weak protolytes and change color in solution according to the pH or on change in hydrogen ion concentration (Okoduwa, Mbora, Adu, & Adeyi, 2016). Such types of indicators may have toxic effects, cause environmental pollution, high cost, less availability and sometimes low color range (Bhagat, Patil, Channekar, Shetty, & Akarte, 2008; Kadam, Yadav, Raje, & Waghmare, 2013).

Despite these, natural indicators extracted from plants like onion, cherry, blueberry, beetroot, red cabbage, peach, pear, grapes, tomato, rose, turmeric, etc. are safe, less expensive, easily available, have fewer side effects, biodegradable, green and eco-friendly (Ayodele, Hawa, & Tawakalitu, 2020; Ogbuanu & Ike, 2018; Pathade, Patil, Kondawar, Naikwade, & Magdum, 2009). Such indicators are highly colored, simple, easy to extract and show promising results as compared to synthetic indicators in the titrimetric analysis (Gyanodaya, Mandir, & Narsingarh, 2015; Jaspreet, Kanika, Nain, & Geeta, 2011). These natural indicators contain different organic compounds like anthocyanin, flavonoids, curcumin, carotenoids, betaine and flavones that are responsible for proton transformation (Bahadori & Maroufi, 2016; Divya, Dipen, Kirtan, Ashish, & Avinash, 2016; Nair & Patil, 2011; Senathirajah, Rasalingam, & Ganeshalingam, 2017; Tukiran & Wardana, 2018).

The titrimetric analysis is the most frequently applied method for acid-base estimation or hydronium ion concentration (Adusei, Adosraku, Oppong-Kyegyeku, & Amengor, 2019) requiring specific chemicals, glassware and handling. On the other hand, pH paper strips are used broadly to test the acidic or basic nature of solution (Song & Osada, 2021; Yoo & Yoo, 2020) and just like litmus paper are cheap, available easy to use and store as well as show comparable results (Metheny et al., 2017; Sri Sruthi et al., 2021).

Regarding this in mind, we designed to prepare natural pH paper strips having the aim to explain their significance. pH paper strips were prepared from *Curcuma longa* (Turmeric), *Rosa indica* (Rose), *Beta vulgaris* (Beetroot) and *Brassica oleracea* (Red-Cabbage) due to their easy availability, non-toxicity, eco-friendly nature, low cost, ease to prepare (even though a simple paper) and durable i.e., give same results even after a couple of months and their colors do not fade out. We have taken 59 domestic chemicals (household chemicals) and 14 samples of standard solutions (HCl and NaOH) of pH 1-14 for comparison. The results obtained from natural indicators are the same as from synthetic ones. In addition, the experiment can be carried out at homes in administrative segregation and solitary confinement in case of pandemic to overcome the disruption of learning. Natural indicators are the best alternative for present days as all over the world corona has almost ceased economy and education. Keeping in view all the above premiums researchers are now working in the field of natural indicators as they proved to be safer substituent for commercial indicators.

2. Material and method

2.1. Plant selection

For the preparation of pH paper strips, we select four plants due to their easy availability. *Curcuma longa* commonly known as Turmeric or Haldi is yellow colored spice containing a high concentration of curcumin; *Rosa indica* is also known as Rose or Cyme Rose or Ghulab, *Beta vulgaris* is a red-colored vegetable commonly known as Beetroot or Red-beet with an active ingredient betacyanin and *Brassica oleracea* Capitata Group is the kind of cabbage with red or purple colored leaves due to the presence of anthocyanin, therefore, known as Red-cabbage. Preparation of pH-paper Indicator Strips.

2.2. Preparation of pH-paper indicator strips

Above mentioned plants were purchased from the local market of Bahawalpur. Before extraction, these were washed and cleaned to remove any dirt. For the preparation of pH indicator strips, the solution was extracted according to the reported method, 15g of *Curcuma longa*, 250g *Beta vulgaris*, 500g *Rosa Indica* or 500g *Brassica Oleracea* was boiled with 100ml deionized water for 10 minutes. The solution was cooled at room temperature and filtered with Watman filter paper. A plain white computer paper was dipped for 15 min in the extracted solution for uniform coloration, dried in air for 12 hours and cut into 6.9cm x 1.5cm (length x width) strips (Fig. 1). Some turmeric paper indicator strips were dipped into sodium hydroxide solution to prepare red colored basic strips.



Figure 1. pH indicator strips of turmeric (acidic & basic), rose, beetroot, red cabbage

These prepared paper indicator strips were used for the detection of acid-base characteristics of fifty-nine household chemicals including milk, soap, toothpaste, honey, ketchup, etc. as well as fourteen standard solutions ranging from pH 1-14. The pH of the standard solutions was maintained using a universal buffer with a pH range of 2-14.

3. Results and discussions

Due to COVID our educational, as well as experimental learning, are disturbed a lot. Students and teachers were stuck at home; laboratory experiments were closed or terminated. Therefore, it is necessary to adopt some chemistry experiments that can be used in the pandemic era and students easily learned the basics of chemistry while staying at home. For this purpose, we select paper indicator experiments that can be prepared at home as well. In our homes, we use a lot of chemicals in our daily life without knowing their nature or properties. In acid-base reactions, indicators are not only used to determine the endpoint (slow or sharp color change) but also tell the nature (acidic or basic). To measure the nature or strength of acids and bases pH papers are commonly used. These pH papers are usually cheap, readily available, eco-friendly and easily stored. Unfortunately, some known pH papers fade their color when stored for a long time which means there should be some detection error. These pH papers are purchased from the market which increases their cost and is sometimes not readily available. To overcome this, here we prepared pH paper strips from natural sources (plants) that gave comparable results with synthetic pH papers available in the laboratory. For comparative studies, the acidic or basic nature of seventy-three samples was measured including fifty-nine household chemicals like milk, vinegar, soap, shampoo, toothpaste, etc., and 14 standard solutions of pH ranging from 1-14.

3.1. Plant Selection for pH-paper indicator

Four plants *Curcuma longa* (turmeric), *Rosa indica* (rose), *Beta vulgaris* (beetroot) and *Brassica oleracea* (red cabbage) were used in this research for paper indicator strips preparation. Turmeric (yellow in acids and red in bases) and beetroot (tea pink in acids and purple in bases) show two main distinguishable colors so can be used instead of litmus paper, phenolphthalein, thymolphthalein, bromothymol blue, methyl violet, etc. While rose (pink or purplish pink in acids and purple-blue to bluish green in bases) and red cabbage (reddish pink, pink and violet in acids and blue, sea blue and yellowish green in bases) show a range of colors like pH Paper so a better substitute for it.

3.2. Detecting the nature of household chemicals

A total of seventy-three samples were checked via these prepared pH paper indicator strips and were also compared with commercialized pH papers. Out of these fifty-nine were household chemicals like lemon juice, milk, soap, honey, coffee, tea, potato, vinegar, baking soda, etc., and fourteen were the standard solutions of different pH ranging from 1-14. The pH of standard solutions was maintained by using a universal buffer. All the chemicals were categorized in different categories depending on the nature of substances strong acids, weak acids, neutral, weak base and strong base.

3.3. Strong Acids

Among the tested household chemical, Harpic is supposed to be the strongest acid due to the lowest pH value. Harpic turns turmeric acid and basic paper bright yellow, rose and beetroot paper into dark pink, red cabbage and pH paper into dark red indicating its pH below 01. Similarly, battery acid also showed a pH near 01. Lemon juice, coca cola, vitamin C and vinegar are also acetic due to the presence of citric acid, ascorbic acid, carbonic acid, phosphoric acid and acetic acid ranges 2-3. For these, turmeric paper turns yellow, rose and beetroot paper turns pink while red cabbage and pH paper turn reddish orange (Fig. 2). Their nature was confirmed by comparing with standard solution (Fig. 6).





































Sr. No.	Sample	Turmeric-A	Turmeric-B	Rose	Beet root	Red cabbage	pH paper
01	Harpic						
02	Battery acid						
03	Lemon juice						
04	Coca cola						
05	Vitamin C						
06	Vinegar						

Figure 2. Strong acidic household chemicals

3.4. Weak acids

Most household chemicals like shampoo, mouth wash, face wash, bread, ketchup, dairy products, fruits and vegetables contain small amounts of malic acid, citric acid, ascorbic acid, lactic acid, or oxalic acid, therefore supposed to be weak acids or mild acids with a pH value 4-6. For these, pH indicator strips showed no color change for acidic turmeric paper (remains yellow) and very little color change for basic turmeric paper (yellow or light orange). Rose indicator strips change to purplish pink or pink, beetroot paper to pink or light pink, red cabbage to pinkish purple or light blue while pH paper changed from orange to very light orange. Among all the household chemicals 22 are

supposed to be weak acids due to corrected results (Fig. 3) and also were compared with the pH value of standard solutions to confirm their nature.

Sr. No.	Sample	Turmeric-A	Turmeric-B	Rose	Beet root	Red cabbage	pH paper
07	Apple						
08	Peach						
09	Orange						
10	Apricot						
11	Soy sauce						
12	Chili sauce						
13	Banana						
14	Coffee						
15	Tomato						
16	Sprite						
17	Ketchup						
18	Bread						
19	Honey						
20	Lotion						
21	Sanitizer						
22	Guava						
23	Shampoo						
24	Potato						
25	Butter						
26	Mango						
27	Face wash						
28	Rose water						
29	Aleo vera gel						
30	Mouth wash						

Figure 3. Weak acidic household chemicals

3.5. Neutral Substances

There are some household chemicals like water, sugar, salt, blood, rain, milk, flour, etc., neutral in nature. For such chemicals, all indicator papers remain unchanged or negligible changed except commercially available pH paper that turns light green (Fig. 4). The pH of these chemicals is supposed to be neutral due to self-ionization or the presence of both acidic and basic component



























































































Sr. No.	Sample	Turmeric-A	Turmeric-B	Rose	Beet root	Red cabbage	pH paper
							
31	Water						
32	Epsom salt						
33	Sugar						
34	Salt						
35	Urea						
36	Blood						
37	Olive						
38	Milk						
39	Flour						
40	Fish						
41	Rain						
42	Sweat						
43	Saliva						
44	Tea						

Figure 4. Neutral household chemicals

3.6. Weak bases

Some household chemicals are weakly basic in nature e.g., egg white, toothpaste, dates, green tea, etc. Such chemicals showed a clear change for acidic and basic turmeric indicator papers (orange or brownish orange); purple or sea green for rose indicator paper; blue or green for red cabbage and pH paper but a very little change for beetroot indicator paper (Fig. 5). These basic chemicals are necessary for natural pH balance like alkaline soil is more fertile as compared to acidic. Similarly, Dettol and toothpaste are basic in nature to remove dirt or stains. Green tea and dates are also basic and maintain the body's pH level. Most of these basic chemicals contain sodium or amino groups and also have a low concentration of hydrogen ions.

Sr. No.	Sample	Turmeric-A	Turmeric-B	Rose	Beetroot	Red cabbage	pH paper
45	Egg white						
46	Dettol						
47	Glycerin						
48	Soil						
49	Toothpaste						
50	Dates						
51	Green tea						
52	Borax						

Figure 5. Neutral household chemicals

3.7. Strong bases

In our daily life, we use some household chemicals that are strongly basic like backing soda, cement, lemon max, etc. For such types of chemicals, turmeric indicator paper changes to red, rose to yellow, beetroot to light pink, red cabbage to lemon yellow or yellow and pH paper to dark purple or blue; except chlorine bleach that only fades color due to chlorate ion (Fig. 6).

Sr. No.	Sample's pH	Turmeric-A	Turmeric-B	Rose	Beetroot	Red cabbage	pH paper
53	Lemon max						
54	Soap						
55	Cement						
56	Baking soda						
57	Lime						
58	Chlorine Bleach						
59	Drain cleaner						

Figure 6. Strongly basic household chemicals

To confirm the nature of all tested household chemicals, here fourteen standard solutions were prepared with pH range 1-14 (Fig. 7). This table gives a clear indication of color change for all types of indicator papers for example turmeric paper is yellow in acidic and yellow color brighten as the pH decreases, remain unchanged at pH 7 while on increasing pH red shade darkens. Rose indicator paper is originally purple but on increasing pH color changed to pink-pinkish purple-purple-bluish green-green-yellow. Beetroot indicator paper on increasing pH changed to pink or purple. Red cabbage and

pH indicator paper show a variety of beautiful colors (red-orange-pink-purple-blue-green-lemon yellow-yellow) for red cabbage and (intense red-orange-orange brown-green-blue-dark blue-purple-blackish purple) for pH indicator paper.

Sr. No	Sample's pH	Turmeric-A	Turmeric-B	Rose	Beetroot	Red cabbage	pH paper
60	1						
61	2						
62	3						
63	4						
64	5						
65	6						
66	7						
67	8						
68	9						
69	10						
70	11						
71	12						
72	13						
73	14						

Figure 7. Standard solution with pH rang 1-14

4. Conclusion

As the synthetic indicator paper strips are costly, unsafe, impermanent and not easily assessable, therefore, we need such paper indicators that not only overcome these problems but can also be prepared easily. Here, we prepared five different types of paper indicator strips for acid-base detection from plants like *Curcuma longa* (turmeric), *Rosa indica* (rose), *Beta vulgaris* (beetroot) and *Brassica oleracea* (red cabbage). From the obtained results, it is divulged that natural indicators show comparable results as synthetic indicators but in less time. For better comparison, we use a total of 59 different household chemicals like water, milk, honey, sugar salt, soap, shampoo etc., and standard solutions for confirmation of their acid-base nature. It was surprising that these indicator strips showed almost the same results as reported in the literature. From the results it was concluded that turmeric acidic and turmeric basic indicator paper yellow in acids and red in basic solutions, further yellow color brightens with the decrease of the pH and red color intense with an increase of pH. Beetroot indicator paper turns dark tea pink in acids while purplish pink in the base. Similarly, rose indicator paper gives different colors pink-purplish pink- purple-blue-bluish green-green and yellow as the pH increases. Red cabbage beautifully explains the nature of acids and bases as it shows visible color change as compared to all other synthesized indicator paper strips like bright red for strong acids, pinkish for weak acids, blue for neutral, bluish green or green for weak bases and lemon green or yellow for strong bases. From this study, it is confirmed that these natural indicator paper strips are economical and very useful as compared to synthetic ones. As, these experiments were accomplished

during COVID-19 pandemic at home-based laboratory, therefore, it will be helpful for chemistry students for understanding and learning during any pandemic.

5. Conflicts of interest

No conflict of interest was declared by the authors.

6. References

- Adusei, E. B. A., Adosraku, R. K., Oppong-Kyekyeku, J., & Amengor, C. D. K. (2019). Investigation of Acid-Base Indicator Property of Plumbagin from *Plumbago zeylanica* Linn. *International journal of analytical chemistry*, 2019, 4061927-4061927. doi: 10.1155/2019/4061927
- Andrews, J. L., de Los Rios, J. P., Rayaluru, M., Lee, S., Mai, L., Schusser, A., & Mak, C. H. (2020). Experimenting with At-Home General Chemistry Laboratories During the COVID-19 Pandemic. *J Chem Educ*, 97(7), 1887-1894. doi: 10.1021/acs.jchemed.0c00483
- Ayodele, O., Hawa, O., & Tawakalitu, B. (2020). The use of plant extracts as indicators in teaching acid- base titrations: Case of *Hibiscus sabdariffa* (Zobo), *Beta vulgaris* (Beet root), *Hibiscus rosa sinensis* and *Acalypha wilkesiana*. *IJET*, 4(4), 53-61. doi: 10.31248/IJET2020.087
- Bahadori, A., & Maroufi, N. M. (2016). Volumetric Acid-Base Titration by using of Natural Indicators and Effects of Solvent and Temperature. *Austin Chromatogr*, 3(1), 1041.
- Barbosa, J. (2005). Indicators| Acid-Base. In P. Worsfold, A. Townshend & C. Poole (Eds.), *Encyclopedia of Analytical Science (Second Edition)* (pp. 360-371). Oxford: Elsevier.
- Bhagat, V., Patil, R., Channekar, P., Shetty, S., & Akarte, A. (2008). Herbal indicators as a substituent to synthetic indicators. *Int J Green Pharm*, 2. doi: 10.4103/0973-8258.42735
- Bhise, S., Shinde, N., Surve, B., Pimpodkar, N., & Shikalgar, S. (2014). *Acalypha wilkesiana* as Natural pH Indicator. *Int j nat prod res*, 4, 33-35.
- Bhuvaneshwari, B., Sivaelango, G., Parthiban, D., Arun, N., & Kumaravel, P. (2015). Natural Dyes as Acid-Base Indicators from *Beta vulgaris*. *Res J Pharmaco Phytochem*, 7, 65. doi: 10.5958/0975-4385.2015.00012.6
- Caraballo, R. M., Saleh Medina, L. M., Gomez, S. G. J., Vensaus, P., & Hamer, M. (2021). Turmeric and RGB Analysis: A Low-Cost Experiment for Teaching Acid-Base Equilibria at Home. *J Chem Educ*, 98(3), 958-965. doi: 10.1021/acs.jchemed.0c01165
- Dennis, M. J. (2020). The impact of COVID-19 on the world economy and higher education. *Enroll Manag Rep*, 24(9), 3-3. doi: <https://doi.org/10.1002/emt.30720>
- Divya, K., Dipen, K., Kirtan, P., Ashish, P., & Avinash, K. (2016). Extract of *Euphorbia milii* flower: A natural indicator in acid-base titration. *J Integr Health Sci*, 4(2), 2-6. doi: 10.4103/2347-6486.240196
- Ghatage, T. S., Killedar, S. G., Hajare, M. A., & Joshi, M. M. (2017). Extraction, Characterization and Utilization of Different Plant Pigments as PH Indicators in Titrimetric Analysis. *Int J Adv Res Ide innov Tech*, 3.
- Gyanodaya, T., Mandir, V., & Narsingarh. (2015). Green chemistry: Study of acid-base indicator property of golden beet root. *Int J Res Granthaalayah*, 3, 1-6. doi: 10.29121/granthaalayah.v3.i9SE.2015.3151
- Haleem, A., Javaid, M., Vaishya, R., & Deshmukh, S. G. (2020). Areas of academic research with the impact of COVID-19. *Am J Emerg Med*, 38(7), 1524-1526. doi: 10.1016/j.ajem.2020.04.022
- Hanson, A. L. (2018, 2021/10/16/). Acid-base indicators. from <https://www.accessscience.com/content/acid-base-indicators/004600>
- Jaspreet, S., Kanika, A., Nain, P., & Geeta, D. (2011). Herbal indicators as an upcoming trend in titrimetric analysis. *Int Res J Pharm*, 2.
- Kadam, S., Yadav, A., Raje, V., & Waghmare, K. (2013). Comparative study of natural and synthetic indicators. *Der Pharma Chem*, 5(1), 296-299.
- Metheny, N., Gunn, E., Rubbelke, C., Quillen, T., Ezekiel, U., & Meert, K. (2017). Effect of pH Test-Strip Characteristics on Accuracy of Readings. *Crit Care Nurse*, 37, 50-58. doi:

10.4037/ccn2017199

- Mishra, L., Gupta, T., & Shree, A. (2020). Online teaching-learning in higher education during lockdown period of COVID-19 pandemic. *Int J Educ Res*, *1*, 100012. doi: <https://doi.org/10.1016/j.ijedro.2020.100012>
- Nair, S., & Patil, S. (2011). Eco-friendly Indicator from the Leaf Extract of *Alternanthera dentata*. *Res J Pharm Technol*, *4*(3), 1095-1097.
- Ogbuanu, C. C., & Ike, C. O. (2018). Leaves extract of *phyllanthus muellerianus* used as a natural indicator in acid base titration. *Int Res J Nat App Sci*, *5*(4), 257-261.
- Okoduwa, S. I. R., Mborah, L. O., Adu, M. E., & Adeyi, A. A. (2015). Comparative Analysis of the Properties of Acid-Base Indicator of Rose (*Rosa setigera*), Allamanda (*Allamanda cathartica*), and Hibiscus (*Hibiscus rosa-sinensis*) Flowers. *Biochem Res Int*, *2015*, 381721. doi: [10.1155/2015/381721](https://doi.org/10.1155/2015/381721)
- Okoduwa, S. I. R., Mborah, L. O., Adu, M. E., & Adeyi, A. A. (2016). Comparative analysis of the properties of acid-base indicator of Rose (*Rosa setigera*), Allamanda (*Allamanda cathartica*), and Hibiscus (*Hibiscus rosa-sinensis*) flowers. *Biochem Res Int*.
- Pathade, K., Patil, S., Kondawar, M., Naikwade, N., & Magdum, C. (2009). Morus Alba Fruit Herbal alternative to synthetic Acid Base indicators. *Int J Chemtech Res*, *1*, 549-551.
- Pietrzyk, D. J., & Frank, C. W. (1979). Chapter Eight - Neutralization in Analytical Chemistry. In D. J. Pietrzyk & C. W. Frank (Eds.), *Analytical Chemistry* (pp. 131-198): Academic Press.
- Rashid, S., & Yadav, S. S. (2020). Impact of Covid-19 Pandemic on Higher Education and Research. *IJHD*, *14*(2), 340-343. doi: [10.1177/0973703020946700](https://doi.org/10.1177/0973703020946700)
- Saggiomo, V., & Velders, A. H. (2021). Experiments@home. *Nat Rev Chem*, *5*(6), 365-366. doi: [10.1038/s41570-021-00285-2](https://doi.org/10.1038/s41570-021-00285-2)
- Senathirajah, T., Rasalingam, S., & Ganeshalingam, S. (2017). Extraction of the Cyanidin-3-Sophoroside from *Hibiscus Rosa-Sinensis*: An Efficient Natural Indicator over a Wide Range of Acid-Base Titrations. *J Nat Prod Plant Resour*, *7*(3), 1-7.
- Song, Q., & Osada, K. (2021). Direct measurement of aerosol acidity using pH testing paper and hygroscopic equilibrium under high relative humidity. *Atmos Environ*, *261*, 118605. doi: <https://doi.org/10.1016/j.atmosenv.2021.118605>
- Sri Sruthi, P., Balasubramanian, S., Senthil Kumar, P., Kapoor, A., Ponnuchamy, M., Mariam Jacob, M., & Prabhakar, S. (2021). Eco-friendly pH detecting paper-based analytical device: Towards process intensification. *Anal Chim Acta*, *1182*, 338953. doi: <https://doi.org/10.1016/j.aca.2021.338953>
- Thomas, O., & Brogat, M. (2017). Chapter 3 - Organic Constituents. In O. Thomas & C. Burgess (Eds.), *UV-Visible Spectrophotometry of Water and Wastewater (Second Edition)* (pp. 73-138): Elsevier.
- Tukiran, T., & Wardana, A. (2018). *Thunbergia erecta* L. Flower as an alternative acidbase natural indicators. *Rasayan J Chem*, *11*, 773-779. doi: [10.7324/RJC.2018.1121844](https://doi.org/10.7324/RJC.2018.1121844)
- Vadivel, E., & Chipkar, S. D. (2016). Eco-friendly natural acid-base indicator properties of four flowering plants from western ghats. *Int J Pharm Pharm.Sci*, *8*(6), 250-252.
- Verschuur, J., Koks, E. E., & Hall, J. W. (2021). Global economic impacts of COVID-19 lockdown measures stand out in high-frequency shipping data. *PLOS ONE*, *16*(4), e0248818. doi: [10.1371/journal.pone.0248818](https://doi.org/10.1371/journal.pone.0248818)
- Yoo, Y., & Yoo, W. S. (2020). Turning Image Sensors into Position and Time Sensitive Quantitative Colorimetric Data Sources with the Aid of Novel Image Processing/Analysis Software. *Sensors*, *20*(22), 6418.