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RESEARCH LETTER

Correlation of pH with beverage's temperature and titratable acidity level of beverages: A quasi-experimental study

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pH is the concentration of free protons (H^+ ions) in a beverage that dissociates from acids. pH indicates the acid strength of a beverage, which means its capability to neutralise a base.[1] pH value less than 7 means the beverage is acidic.[2,3] The activity and concentration of ions in a beverage may be affected by the beverage's temperature, which is related to the pH.[3] It may happen due to a decreased tendency of hydrogen bond formation.[3,4] The molecular equilibrium of a beverage may change in state due to temperature changes, thereby affecting the physio-chemical nature of the beverage.[4] Though pH is the concentration of free protons (H^+ ions), titratable acidity measures the sum of free protons (H^+ ions) and undissociated acids in a beverage. Titratable acidity is a measure of the total acidity of a beverage, usually expressed in grams per litre (g/L) or as a percentage of the total acid content of a solution.[4,5] It is essential to assess whether the pH level or free of H^+ ions in beverages depends on the total acid content (g/L or %) or not.[5] A low pH level in a beverage is associated with complications such as metabolic acidosis and dental erosion.[5,6] Most previous studies have focused on the pH of different beverages, but literature on the titratable acidity level and temperature of the beverages is scarce.[6] A quasi-experimental study was conducted to correlate the pH of the beverage with its temperature and beverages' pH and titratable acidity levels.

LEARNING POINTS

1. The beverage's pH level (acidity indicator) is inversely related to its temperature.
2. A beverage's pH level has a negative correlation with its titratable acidity level.
3. It is recommended that beverages be consumed at the coolest temperature to prevent complications such as metabolic acidosis or dental erosion.

Carbonated beverages, apple cider vinegar, commercial fruit juice (mango juice), wine, distilled spirit, and beer were included as study samples. The most consumed non-alcoholic beverages were selected by survey, while alcoholic beverages were chosen based on anecdotal evidence. Carbonated beverages, fruit juice, and beer were not diluted, but wine (1:1), distilled spirit (1:1), and apple cider vinegar (3:25) were diluted with water as per the manufacturer's instructions. The pH level of six beverages (n=30, 5 samples for each beverage group) was measured using a pH Meter (HANNA), and the temperature (^oC) of the attributed beverages was monitored using the pH Meter with automatic temperature compensation systems. The experimental trial was conducted at a controlled room temperature (37^oC) at the Department of Chemical Engineering, Bangladesh University of Engineering and Technology Laboratory. NaOH (0.13N) strong base was used as the titrant for measuring the titratable acidity level (g/L) of beverages (n=30, 5 samples for each beverage group).

The findings indicated a very strong inverse correlation (r=-0.96) between pH and temperature of beverages. The correlation between the pH level and titratable acidity (g/L) level of the beverages was a weak inverse relationship (r=-0.36).

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This study's findings indicated that the concentration of hydrogen ions, which lowers the pH level, does not depend on the attributed beverage's total acid content (g/L). The pH (ionised H^+ concentration) may depend on physical properties such as molecular vibrations in the beverage, which result in the ionisation and formation of H^+ ions, temperature, and other factors.[6, 7] The changes in temperature of a beverage at equilibrium allow the system to change its state to nullify the effect of temperature.[7] In this study, temperature influenced a system's equilibrium state and affected the beverages' pH.[7, 8] Probably, increased temperature decreases the pH level of beverages. Higher temperatures may increase molecular vibrations in the solution, resulting in more ionisation and formation of H^+ ions, leading to a more acidic nature. When a beverage's temperature rises, molecular vibrations may increase, enhancing the beverage's ability to ionise into hydrogen ions.[8] Based on Le Chatelier's principle, a chemical system in a state of equilibrium will respond to changes by shifting the equilibrium to counteract those changes.[8, 9] Temperature is considered a probable cause for such changes in a chemical system.[9]

Additionally, there is often a misconception regarding the association between pH and titratable acidity.[9, 10] This study also illustrated that a lower pH (highly acidic) does not necessarily mean higher titratable acidity in a beverage. The beverage's acidity level may depend on the physical properties of the organic/ inorganic acids presented in a beverage.[10]

To conclude, a lower pH of a beverage was observed to be associated with a higher beverage temperature but not with higher titratable acidity of a beverage. Beverage consumption at the coolest possible temperature is recommended to prevent complications of beverage acidity, such as metabolic acidosis or dental erosion.

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Author contributions

Conception and design: MAHRA, MAAM, AKMB. *Acquisition, analysis, and interpretation of data:* RA. *Manuscript drafting and revising it critically:* RA, MAAM, AKMB. *Approval of the final version of the manuscript:* RA, MAAM, AKMB. *Guarantor of accuracy and integrity of the work:* RA, MAAM, AKMB.

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Conflict of interest

We do not have any conflict of interest.

Ethical approval

This study was conducted after obtaining ethical permission from the Institutional Review Board of Bangabandhu Sheikh Mujib Medical University (IRB memo number: BSMMU/2021/12935 and date: 26/12/2021). Before performing lab work, permission was taken from the Department of Chemical Engineering, BUET.

Data availability statement

We confirm that the data supporting the findings of this study will be shared upon reasonable request.

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