Development of a Portable, Low-Cost Miniaturized System for Colorimetric pH Measurement in Saliva

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ABSTRACT

Bromothymol blue (BTB), with a pKa of 7.1, is a pH indicator that changes color from yellow (pH < 6.0) to green (pH 6.0–7.6), and to blue (pH > 7.6), exhibiting peak light absorption in the visible range at 430 nm (protonated form) and 620 nm (deprotonated form) [1]. Its transition range matches that of biological fluids, making it suitable for clinical applications such as saliva analysis [2]. A 3D-printed device was developed using the AS7341 color sensor, which detects eight channels across different wavelengths (415 to 680 nm) [3]. Based on optimized data from previous studies, the 590 nm channel showed the best performance, with a linear range from pH 5.7 to 7.1, described by the equation Y = -15552 × pH + 140395 (R^2 = 0.995). Two saliva samples were collected using Salivette® tubes and analyzed with the proposed method, yielding pH values of 6.80 and 7.00. Measurements with a conventional pH meter were 6.83 and 7.03, respectively, demonstrating statistical agreement. This setup offers an accessible, low-cost approach for accurate pH analysis in clinical, research, and environmental settings.

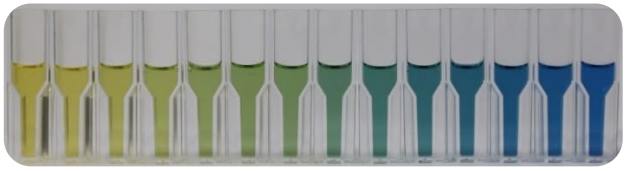
Keywords: Optical sensors, Colorimetric determination, Clinical analysis, Analytical Instrumentation.

Introduction

Bromothymol blue (BTB), with a pKa of 7.1, functions as an acid-base indicator that appears yellow in its protonated form at pH values below 6.0. It changes color to green between pH 6.0 and 7.6, and transitions to blue at pH values above 7.6. This indicator exhibits distinct spectral characteristics depending on its ionic state, absorbing visible light most strongly near 430 nm when protonated and around 620 nm when deprotonated [1].

Therefore, bromothymol blue is a valuable choice for pH determination, offering a distinct color transition within a pH range relevant to biological fluids. This makes it well-suited for applications in clinical diagnostics and health monitoring. It is commonly used in the analysis of fluids such as saliva, which has slight buffering capacity and generally exhibits pH values near 7 in healthy individuals [2].

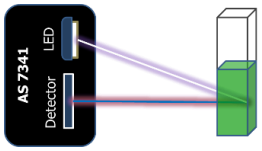
Figure 1: Solutions of the bromothymol blue in different values of pH´s (5.52; 5.70; 5.91; 6.10; 6.30; 6.40; 6.70; 6.90; 7.10; 7.30; 7.51; 7.70; 7.90).



Experimental

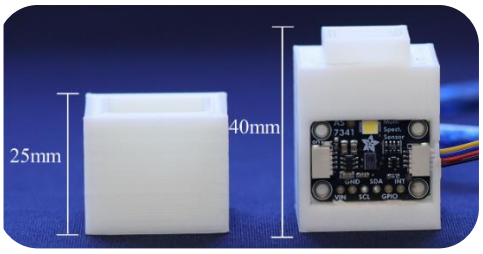
For the pH analysis, the AS7341 multichannel color sensor from Adafruit was employed. This sensor simultaneously monitors eight channels at different wavelengths (415, 445, 480, 515, 555, 590, 630, and 680 nm), allowing adjustment of parameters such as LED current and gain [3].

Figure 2: Illustration depicting the operation of the AS7341 color sensor during analysis.



With the sensor, a 3D-printed structure was developed and attached to an Arduino UNO microcontroller, which is necessary for handling the AS7341 sensor.

Figure 3: Photo taken on the developed analytical system



The analyzed solution has a ratio of 2:3 saliva sample to 1:3 BTB solution, requiring a minimum of 0.9 mL of total solution to be analyzed in the device (0.6 mL of saliva and 0.3 mL of BTB). Salivette®.

Saliva was collected using a Salivette® tube from Prismalab. The centrifugations condition were 1000 x g for 2 minutes.

For the pH of standard solutions prepared from aqueous monosodium phosphate buffer solutions (50% v/v and 0.5 mol/L) using external calibration.

Results and discussion

Figure 5: Spectrum of the BTB indicator in the Spectrophotometer Shimadzu UV-2501PC at different pH values.

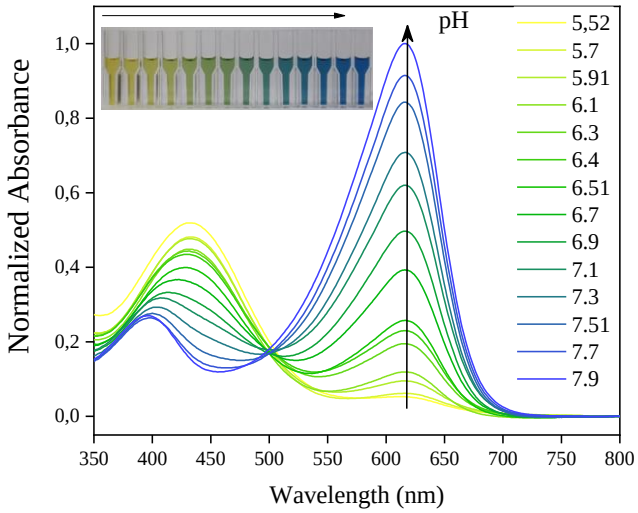


Figure 6: Response of the AS7341 sensor in the 415, 445, 480, 515, 555, 590, 630, and 680 nm channels to the indicator.

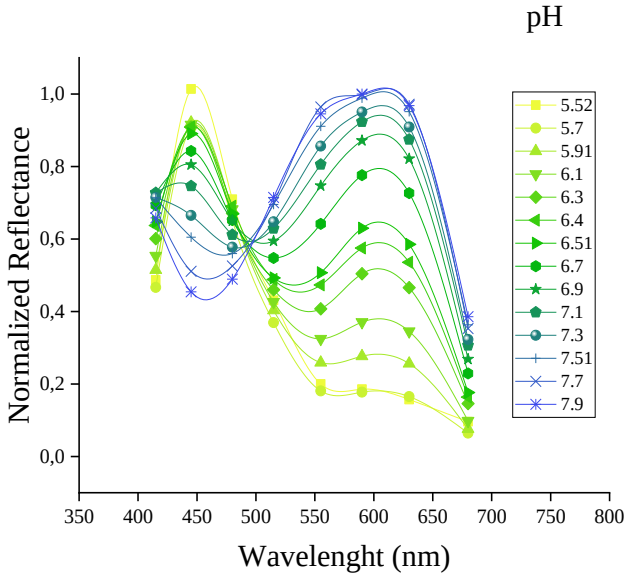
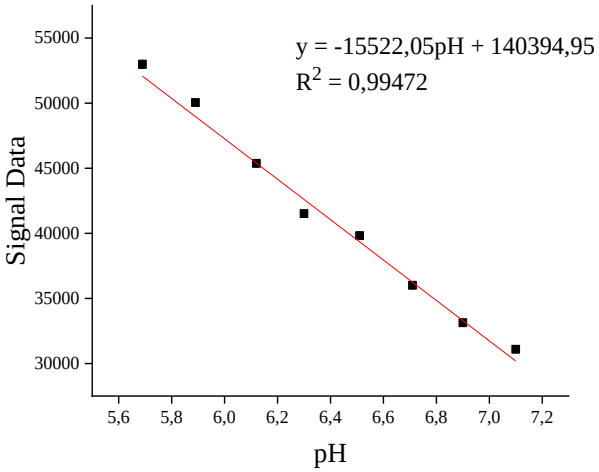


Figure 7: Calibration curve with triplicates of standard solutions at pH values of 5.69, 5.89, 6.12, 6.3, 6.51, 6.71, 6.9, and 7.1.



The calibration curve was performed using the 590 nm channel of the AS7341, with a concentration of 40 µmol/L of the indicator in each standard solution and in each saliva sample solution.

Table 1: Two saliva samples from two different individuals were analyzed, first using a pH meter and then with the proposed device.

	pH value obtained in AS7341	**pH value in pH meter**
Sample 1:	6,80	6,83
Sample 2:	7,00	7,03

Conclusion

Thus, the AS7341 color sensor combined with a 3D-printed structure and the use of BTB for pH indication offers a accuracy and cost-effective solution, enhancing the accessibility and affordability of pH measurement. These advantages are especially important in settings with restricted budgets, allowing for precise and efficient analysis in diverse environments, including research laboratories, clinical settings, and environmental monitoring.

Acknowledgments

FAPEMIG, CNPq and CAPES

References

[1] J.C. de Andrade, *Chemkeys*, **2023**, Vol. 5

[2] F.G. Bellagambi; T. Lomonaco; P. Salvo; F. Vivaldi; M. Hangouet; S. Ghimenti; D. Biagini; F. Di Francesco; R. Fuoco; A. Errachid, *Trends in Analytical Chemistry*, **2020**, 124, 115781.

[3] C. C. S. Machado; A. N. S. Cadeado; Y. S. N da Mota; J. F. S. Petruci; S. G. Silva, *Anal. Methods*, **2024**,16, 8427-8436