Research Article Open-Access

Bioactive Compounds in Health and Disease

Evaluating acidity levels in packaged coffee to enhance product label accuracy

Abdulhakim Sharaf Eddin, Philip Junior Yeboah, Salam A. Ibrahim*

Food Microbiology and Biotechnology Laboratory, Food and Nutritional Sciences Program, North Carolina A&T State University, Greensboro, NC 27411, USA.

***Corresponding author**: Salam A. Ibrahim, Food and Nutritional Sciences Program, North Carolina A&T State University, 1601 E. Market Stree, Greensboro, North Carolina, 27411, USA

Submission Date: January 25th 2024; **Acceptance Date:** March 5th 2024; **Publication Date:** March 8th, 2024

Please cite this article as: Eddin A. S., Yeboah P. J., Ibrahim S. A. Evaluating Acidity Levels in Packaged Coffee to Enhance Product Label Accuracy. *Bioactive Compounds in Health and Disease* 2024; 7(3): 145-151.
DOI:https://www.doi.org/10.31989/bchd.v7i3.1303

ABSTRACT

Background: Coffee is one of the world's most popular beverages. Coffee is enjoyed for a variety of reasons, including its sensory characteristics. Some sensory characteristics of coffee, such as acidity, are attributed to the levels of various organic acids and chlorogenic acids present in the brew. The amount and composition of these organic acids are considered key factors that influence the acidity of the coffee. Many roasted coffee products on the market claim to be low in acid or even acid-free altogether.

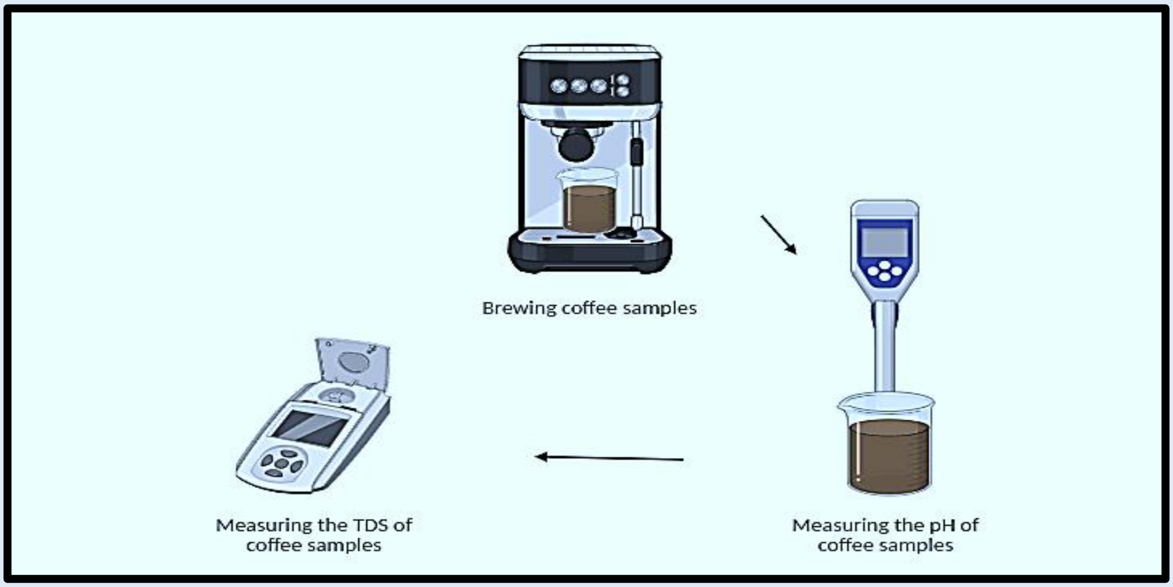
Objective: The objective of this study was to evaluate the acidity of different packaged coffee products.

Materials and Methods: All coffee samples were brewed using the drip method per preparation instructions for each product, and pH values for all samples were measured and recorded.

Results: Our results revealed a wide range of pH values among the tested products, with the highest pH value (pH 5.72) in sample XL96 and the lowest value (pH 4.97) in sample XL10. The pH values for the remainder of the samples ranged between (pH 5.0-5.29). The highest TDS was observed in sample XL10 with a value of (2.7%), and the lower TDS was in sample XL21 with a value of (1%).

Conclusions: The results thus support the importance of creating a standard for the accurate label in the packaged coffee products.

Keywords: Packaged coffee, coffee, acidity, roasting, label, hot brew, total solids



INTRODUCTION

Coffee is believed to have been discovered in the 9th century in a region of East Africa called Ethiopia. The legend of the discovery of coffee involves a goat herder named Kaldi who noticed that his goats became energetic after eating berries from a certain tree, which we now recognize as the coffee plant [1]. Coffee was introduced to Europe in the 17th century, with the first coffeehouse opening in Venice in 1645 [1]. The coffee market is currently valued at 15.1 billion USD and is continuously expanding, consisting primarily of roasted, instant, and ready-to-drink coffee [2]. With 5.7 million tons of Coffea *arabica* (Arabica coffee) and 4.3 million tons of *Coffea canephora* (Robusta coffee), world coffee production is set to reach 10.2 million tons in 2020 [3]. Since caffeine is the primary compound in coffee, it is not surprising that about two-thirds of the daily caffeine intake among adults over the age of ten in the U.S. comes from coffee. Caffeine use has been linked to several health advantages such as improved anti-inflammatory responses, enhanced cognitive function, and hypoalgesic effects [4]. Packaged coffee refers to coffee beans or ground coffee that have been processed, roasted, and sealed in a container for commercial distribution and consumer purchase. The quality and flavor of packaged coffee are influenced by factors such as its origin, roasting methods, packaging materials, and storage conditions. During the roasting process, several reactions take place including the Maillard reactions which are the breakdown of sugars, oxidation of lipids, and pyrolysis thus contributing to the color, flavor, or acidity of coffee [5]. Coffee bean roasting occurs at temperatures of 180–250 °C and depending on the desired roast level (light, medium or dark), many post-roasting compounds can be created. For example, [6] reported that more than 950 compounds could be developed during roasting. The caramelization stage of roasting accounts for coffee's hue, whereas pyrolysis reactions yield both volatile and non-volatile compounds that play a critical role in the aroma and flavor characteristics of coffee [7]. Certain bioactive compounds, specifically total phenolic compounds (TPC) and chlorogenic acids (CGA), undergo progressive degradation because of the roasting process, which is influenced by both the temperature level and the roasting intensity [8]). CGAs, particularly chloroquinic acids, contribute to coffee's bitterness and are recognized for their antioxidant properties, which could potentially offer health advantages to coffee consumers [9]. Another type of acid found in coffee are organic acids (OAs) which have been identified and measured in roasted coffee, the most noticeable being citric, malic, and quinicacids which are typically found in green coffee. As coffee fruit ages, bioactive substances accumulate naturally in the bean and consist of various quinic acid esters or a series of esters, collectively known as CGAs [10]. This accumulation undergoes significant changes in the acid content of coffee beans during the roasting process. For example, green coffee has lower acid levels than roasted coffee, with a pH between 5.8 – 6.1 [11-12]. During the roasting process, chlorogenic, citric, and malic acids are broken down and, as a result of CGA breakdown, quinic acid concentration increases [13]. As a secondary effect, [14] demonstrated that higher roasting temperatures led to the breakdown of CGA, yielding reduced extraction concentrations and leading to a reduction in acidity levels. This result was corroborated by [9] who found a higher concentration of CGA in medium-roast coffee compared to dark roast. This higher CGA concentration caused the dark-roast coffee to be slightly less acidic than the medium roast. However, roasted coffee has a pH range between 4.8-5.2 which is significantly more acidic than green coffee, whose pH ranges between 5.8 - 6.1.

The strength of the beverage and the yield of soluble material extracted from the bed of dry coffee grounds are two fundamental and related brewing indicators that help to define the coffee brewing process. Strength is often measured by way of total dissolved solids (TDS) which is stated as a mass percent and brewing yield, also known as percent extraction (PE), which is the mass of soluble material extracted from the coffee grounds per the original dry mass of grounds. [15].

High-acid coffee can cause stomach discomfort and potential health problems in people who are sensitive to acid. Due to its gentler acidity profile, low-acid coffee was designed to help alleviate stomach discomfort and other potential symptoms that high-acid coffee may have caused. Whereas the average pH of roasted coffee sits below the critical pH line of 5.5 for beverages, coffee causes acidification and discoloration of teeth and is associated with being a leading cause of gastral issues for many consumers [16]. Numerous coffee products are marketed as low-acid coffee and yet only a few studies have actually investigated the acidity levels of the hot-brewed coffees that claim to be low in acidity. Additionally, some coffee packaging labels include claims of the product being acid-free. In this context, the objective of the present study was to examine and compare the differences in acidity levels across various packaged coffee products. Subsequently, the results will serve as a benchmark to support enhanced decision-making in coffee product development and a resultant standard for use on packaging labels of low-acid or acid-free coffee.

MATERIALS AND METHODS

Sampling*:* Eleven commercial products of higher quality ground dark-roasted coffee were purchased from a local grocery store (Greensboro, North Carolina) and an online store (Amazon). All coffee samples claim low-acid coffee. The coffee samples were given codes as XL and stored in a dry environment at room temperature.

Brewing Coffee Samples: The coffee samples were brewed using a drip coffee maker (Mr. Coffee, 12 Cup Switch Coffee Maker) following the brewing instructions on the package for coffee grounds to water ratio for each sample (Table 1). The measured coffee grounds were placed in a clean paper filter (coffee filters, Harris Teeter, unbleached) after filling the coffee maker reservoir with cold deionized water (DI). The coffee pot and filter basket were washed and rinsed with DI water after each coffee-making cycle.

Determination of pH Values: The pH readings were recorded using a pH meter (Accumet AB 150, Fisher Scientific, Pittsburgh, PA) after calibration with standard pH buffers (4.0, 7.0, and 10). The pH values of each coffee sample were measured in triplicate by placing the pH electrode into the sample after cooling down the sample to room temperature (~25 ℃). The pH electrode was rinsed thoroughly with DI water and wiped clean between measurements

Determining Total Dissolved Solids (TDS): TDS refers to the total concentration of dissolved substances including minerals, salts, ions, and other organic and inorganic compounds. The sample should be at room temperature to measure the TDS using a refractometer (Boss Refractometers, National Industrial Supply). A few drops of the coffee samples were placed onto the refractometer's prism surface after which the prism cover was gently closed to ensure no air bubbles or gaps between the prism and the liquid. The reading of TDS (%) was taken in triplicate by looking through the eyepiece of the refractometer until a clear line or boundary could be seen between the light and dark areas.

Statistical Analysis*:* Each experiment was performed for a total of three times and the mean and standard deviation of the results were recorded. Additionally, an analysis of variance using one-way ANOVA was conducted (SAS version 9.4) along with Tukey's test to determine the differences in the mean values of the recorded data values. In order for the results to be considered statistically significant, the p value must be less than 0.05.

Table 1. Brewing method and instructions for coffee samples

Coffee Code	Brewing Method	Instructions
XL96	Drip	2 Tbsp of coffee/8 oz of DI water
XL21	Drip	1 Tbsp of coffee/6 oz of DI water
XL43	Drip	2 Tbsp of coffee/6 oz of DI water
XL76	Drip	2 Tbsp of coffee/6 oz of DI water
XL97	Drip	35 g of coffee/500 ml of DI water
XL65	Drip	30 g of coffee/500 ml of DI water
XL54	Drip	2 Tbsp of coffee/6 oz of DI water
XL10	Drip	2 Tbsp of coffee/6.75 oz of DI water
XL32	Drip	1.5 Tbsp/6 oz of DI water
XL87	Drip	2 Tbsp of coffee/6 oz of DI water
XL98	Drip	2 Tbsp of coffee/8 oz of DI water

RESULTS AND DISCUSSION

Figure 1 shows the pH values of brewing coffee samples, which were all dark-roast in this experiment. The pH measurements for coffee samples displayed a low acidity in sample XL96 (pH 5.74) which was significantly different ($P < 0.05$) from other samples. The higher acidity was observed in samples XL10, XL65, and XL98 (pH 4.96, 4.99, and 5.02) respectively. The pH values for the rest of the samples ranged between pH 5.10 - 5.28 which is within the expected average pH range of the regular commercial coffee. Many factors can affect the final pH level of brewing coffee including the roasting temperature. Heat initiates a series of chemical changes in the coffee beans during the roasting process which alters the flavor profile of the coffee. Moreover, the acidity of coffee can also be affected by the type of roast. The acid composition of coffee beans changes dramatically during roasting. In addition, chlorogenic, citric, and malic acid are degraded, although quinic acid concentration increases due to the presence of CGA degradation [13]. Some bioactive chemicals such as total phenolic compounds and chlorogenic acids break down gradually throughout the roasting process, which is influenced by the roasting temperature and intensity [7].

TDS is a measurement of the concentration of dissolved solids in a liquid, typically expressed in parts per million (ppm) or as a percentage [17]. In the context of brewing coffee, TDS is often used to assess the strength and flavor of the coffee. A higher TDS reading generally indicates a stronger and more concentrated coffee with bolder flavors while a lower TDS reading suggests a milder and potentially under-extracted brew. Figure 2 shows the TDS of brewing coffee samples. The highest TDS was observed in sample XL10 with a value of 2.7% and the lower TDS was in sample XL21 with a value of 1%. Most coffee samples had a TDS range between 1.4-2%. In an analysis of how TDS affected the sensory qualities of drip coffee, [18] concluded that coffee with a lower TDS was sweeter while coffee with a greater TDS was more acidic. The degree of grinding has a significant impact on the physicochemical characteristics of brewing coffee such as pH and TDS. To manage extraction and dispersion, roasted beans must be ground into a smaller size and, as a result, TDS decreases with increasing particle size [19-20]. The TDS in drip coffee is influenced by factors such as the coffee beans chemical composition, the size of the coffee grounds, the roasting temperature, the temperature of the water used for extraction, and the extraction time. [17, 20] indicated that the TDS decreased as the roasting time increased.

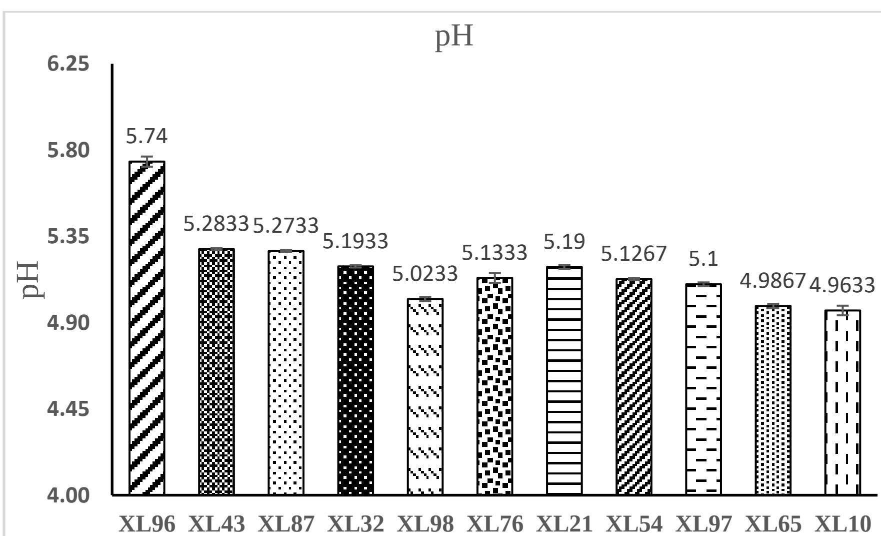


Figure 1. The acidity of **coffee** samples measured by pH **(**Each value is the mean ±SD. Sample size is n = 3 for pH. Superscripts a–f denotes significant ($p < 0.05$) differences between pH values of brewing coffee samples as determined by the Tukey-tests.)

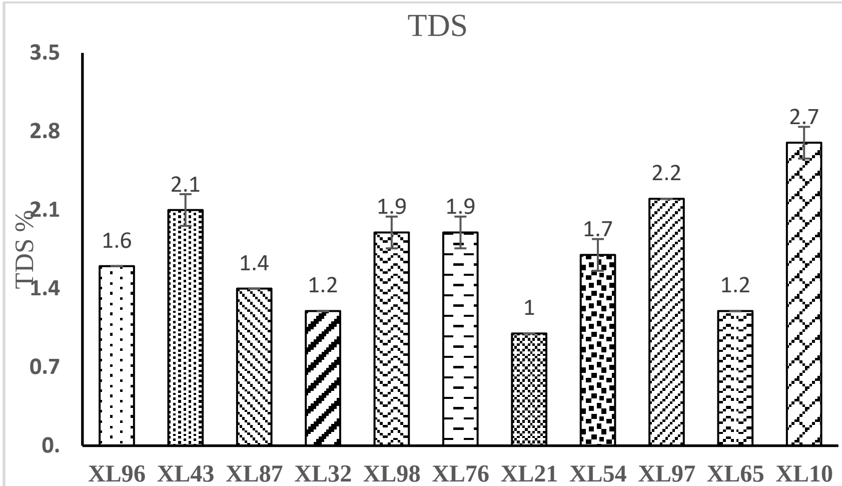


Figure 2. TDS (%) values of coffee samples. (Each value is the mean ±SD. The sample size is n = 3 for TDS. Superscripts a–f denotes significant ($p < 0.05$) differences between TDS values of brewing coffee samples as determined by the Tukey-tests.)

CONCLUSION

In the present study, the pH and TDS values of different commercially packaged coffee products sold in retail stores in North Carolina were evaluated in order to investigate the accuracy of the information on coffee products labeled as low acid or acid-free. Our results showed a significant difference in pH measurements among coffee samples, with only one of the seven low-acid coffee brands tested, being significantly less acidic than average commercial coffee and above the critical pH line (pH 5.5). Based on our study, customers will have access to more accurate information when purchasing roasted coffee that has been labeled as low acid. Our results serve to emphasize the need to establish a reliable set of standards for the labeling of low-acid coffee in packaged coffee products. This effort will help the coffee industry to be better informed on how coffee processing can impact the acidity of the final product. This new standard for low-acid coffee should reference the medical definition of critical pH, include a standardized method for measuring pH, include clear information regarding acidity levels on all packaging labels, and demonstrate assurance from the industry regarding compliance with this new standard.

List of Abbreviations: TPC: Total Phenolic Compounds, CGA: Chlorogenic Acids, OAs: Organic Acids, TDS: Total Dissolved Solids, PE: Percent Extraction, DI: Deionized Water.

Acknowledgements: This publication was made possible by grant number NC.X-267-5-12-170-1 from the National Institute of Food and Agriculture (NIFA) and in part by the Department of Family and Consumer Sciences and the Agriculture Research Station at North Carolina Agriculture and Technical State University (Greensboro, NC 27411). The authors would also like to acknowledge the financial support provided by Puroast Coffee Company, Inc., High Point, NC.

Competing Interests: The authors hereby declare that there are no conflicts of interest.

Authors Contributions: All authors Abdulhakim Sharaf Eddin (ASE), Philip Junior Yeboah (PJY) and Salam A. Ibrahim (SAI) contributed equally to the manuscript. ASE: Wrote the manuscript and conducted the methodology. PJY drew the graphs and supported all laboratory activities. SAI: managed the project, designed the experiment, conducted data analysis, edited the manuscript

References

1. Pendergrast M: Uncommon Grounds: The History of Coffee and How it Transformed Our World. New York: Basic Books; 2010.
2. Seninde DR, Chambers IV E: Coffee flavor: A review. Beverages 2020, 6(3):44. DOI: https://doi.org/10.3390/beverages6030044
3. Velásquez S,Banchón C: Influence of pre-and post-harvest factors on the organoleptic and physicochemical quality of coffee: A short review. Journal of Food Science and Technology 2023, 60(10):2526-38. DOI: https://doi.org/10.1007/s13197-022-05569-z
4. Celli GB, de Camargo AC: What is in a "Cup of Joe"? From green beans to spent grounds: a mini-review on coffee composition and health benefits. Journal of Food Bioactives 2019, 6. DOI: https://doi.org/10.31665/JFB.2019.6185
5. Kocadağlı T, Göncüoğlu N, Hamzalıoğlu A, Gökmen V: In depth study of acrylamide formation in coffee during roasting: role of sucrose decomposition and lipid oxidation. Food & Function 2012, 3(9):970-5. DOI: https://doi.org/10.1039/C2FO30038A
6. Sualeh A, Tolessa K, Mohammed A: Biochemical composition of green and roasted coffee beans and their association with coffee quality from different districts of southwest Ethiopia. Heliyon 2020, 6(12). DOI: https://doi.org/10.1016/j.heliyon.2020.e05812
7. Tarigan EB, Wardiana E, Hilmi YS, Komarudin NA: The changes in chemical properties of coffee during roasting: A review. InIOP Conference Series: Earth and Environmental Science 2022, (Vol. 974, No. 1, p. 012115). IOP Publishing. DOI: https://doi.org/10.1088/1755-1315/974/1/012115
8. Herawati D, Giriwono PE, Dewi FN, Kashiwagi T, Andarwulan N: Critical roasting level determines bioactive content and antioxidant activity of Robusta coffee beans. Food science and biotechnology 2019, 28:7-14. DOI: https://doi.org/10.1007/s10068-018-0442-x
9. Rao NZ, Fuller M, Grim MD: Physiochemical characteristics of hot and cold brew coffee chemistry: The effects of roast level and brewing temperature on compound extraction. Foods 2020, 9(7):902. DOI: https://doi.org/10.3390/foods9070902
10. Yeager SE, Batali ME, Guinard JX, Ristenpart WD: Acids in coffee: A review of sensory measurements and meta-analysis of chemical composition. Critical reviews in food science and nutrition 2023, 63(8):1010-36. DOI: https://doi.org/10.1080/10408398.2021.1957767
11. Araújo CDS, Macedo LL, Vimercati WC, Ferreira A, Prezotti LC, Saraiva SH: Determination of pH and acidity in green coffee using near-infrared spectroscopy and multivariate regression. Journal of the Science of Food and Agriculture 2020, 100(6), pp.2488-2493. DOI: https://doi.org/10.1002/jsfa.10270
12. Bicho NC, Leitão AE, Ramalho JC, de Alvarenga NB, Lidon FC: Identification of chemical clusters discriminators of Arabica and Robusta green coffee. International Journal of Food Properties 2013, 16(4), pp.895-904. DOI: https://doi.org/10.1080/10942912.2011.573114
13. Rune CJ, Giacalone D, Steen I, Duelund L, Münchow M, Clausen MP: Acids in brewed coffees: Chemical composition and sensory threshold. Current Research in Food Science 2023, 6:100485. DOI: https://doi.org/10.1016/j.crfs.2023.100485
14. Trugo LC, Macrae R. A: study of the effect of roasting on the chlorogenic acid composition of coffee using HPLC. Food Chemistry 1984, 15(3):219-27. DOI: https://doi.org/10.1016/0308-8146(84)90006-2
15. Frost SC, Ristenpart WD, Guinard JX: Effects of brew strength, brew yield, and roast on the sensory quality of drip brewed coffee. Journal of Food Science 2020, 85(8):2530-43. DOI : https://doi.org/10.1111/1750-3841.15326
16. Ranjitkar S, Kaidonis JA, Smales RJ: Gastroesophageal reflux disease and tooth erosion. International journal of dentistry 2012. DOI: https://doi.org/10.1155/2012/479850
17. Jung S, Gu S, Lee SH, Jeong Y: Effect of roasting degree on the antioxidant properties of espresso and drip coffee extracted from Coffea arabica cv. Java. Applied Sciences 2021, 11(15):7025. DOI: https://doi.org/10.3390/app11157025
18. Frost SC, Ristenpart WD, Guinard J.X: Effect of basket geometry on the sensory quality and consumer acceptance of drip brewed coffee. Journal of food science 2019, 84(8), pp.2297-2312. DOI: https://doi.org/10.1111/1750-3841.14696
19. Várady M, Tauchen J, Klouček P, Popelka P: Effects of total dissolved solids, extraction yield, grinding, and method of preparation on antioxidant activity in fermented specialty coffee. Fermentation 2022, 8(8):375. DOI: https://doi.org/10.3390/fermentation8080375
20. Iriondo-DeHond A., Ramirez B., Escobar F.V., del Castillo M.D: Antioxidant properties of high molecular weight compounds from coffee roasting and brewing byproducts. Bioactive Compounds in Health and Disease 2019; 2(3):48-63. DOI: https://doi.org/10.31989/bchd.v2i3.588