DOI: 10.46793/SBT29.68IDJ

COW'S MILK IN RELATION TO DIFFERENT PLANT-BASED DRINKS: PHYSICO-CHEMICAL PROPERTIES AND NUTRITIONAL IMPORTANCE

Igor Đurović[1], Miloš Petrović[1], Vesna Matejić[1]

Abstract: In this study, selected physico-chemical properties of cow's milk were compared with plant-based drinks made from rice, buckwheat, quinoa, almonds, and hazelnuts. Analysis such as conductivity, pH value, viscosity, and density were measured using standardized techniques. Further analysis such as protein, fat, SNF (non-fat solids), lactose, and minerals were determined using a milk analyzer.

The results showed that all plant-based drinks had lower values for protein, SNF, lactose, minerals, pH, and conductivity compared to cow's milk. The other parameters showed a different trend, which is described below.

Keywords: cow's milk, plant-based drinks, physico-chemical properties

Introduction

The term milk refers to a white liquid with a specific taste and odor that is secreted by the mammary gland some time after birth in female mammals and is used to feed the young. Cow's milk has a specific composition that distinguishes it from all other liquids of animal or vegetable origin, which corresponds to its purpose and gives it great biological and certain technological value. Some believe that cow's milk is the perfect food, not only for its nutritional value, but also for its moisturizing properties and its contribution to maintaining the body's overall immunity in infants (Khan et al., 2017).

Cow's milk and dairy products made from it play an important role as a food source with high nutritional content that has a positive impact on human health. The composition of cow's milk can vary considerably depending on many variables such as the breed of cattle, the duration of lactation, the health status of the animal, etc. (Leduc et al., 2021).

[1]University of Kragujevac, Faculty of Agronomy, Cara Dušana 34, Čačak, Serbia (igor.djurovic@kg.ac.rs)

There are numerous studies that provide a complete and exhaustive analysis of the chemical composition of commercial cow's milk at the macro- and micronutrient level. These include numerous data on milk proteins, fats, carbohydrates, various bioactive compounds such as vitamins, minerals, organic acids, biogenic amines, oligosaccharides, nucleotides and immunoglobulins (Fox et al., 2015; Foroutan et al., 2019). Today, milk and dairy products are promoted in public health policies worldwide as an important part of the human diet (Comerford et al., 2021).

Recently, more and more average consumers are consuming plant-based substitutes (Beacomi et al., 2021; Vallath et al., 2022). Plant-based drinks (PBDs) are seen as an alternative to milk and are often sold in stores near dairy products and advertised as having better properties and being healthier than milk and dairy products. There are numerous reasons that can explain these changes in eating behavior. Many authors state that the higher proportion of PBDs on the market is the reason for health consequences such as lactose intolerance (Obermayer-Pietsch et al., 2004), but also the lifestyle in general (vegetarian and vegan) (Antunes et al., 2023; McCarthy et al., 2017).

This work is a continuation of an earlier work in which commercially available plant milks (almond and soy milk) were examined and compared with cow's milk (Milovanović et al., 2023).

Materials and methods

Collection of samples: Commercially available samples such as quinoa, buckwheat, hazelnut, almond, rice, and cow's milk were purchased from a local supermarket.

Preparation of PBDs: 100g of previously ground samples and water were mixed in a ratio of 3:1 in favor of water. The extracts were obtained by ultrasonic extraction at 35 °C for 1.5 hours. After the completion of the extraction, filtration was done, and the physico-chemical properties of the PBDs were further analysed.

Physical analysis: A portable conductivity meter CiberScan CON 510 was used to determine the pH and conductivity of milk and PBDs.

Density was determined by lactodensimeter at 20 °C.

Viscosity was determined using the Ostwald viscometer at 20 °C. The time in seconds was converted to dynamic viscosity using the diameter of the capillary and the formula:

$$\eta_x = \eta_{H_2O} \cdot \frac{\rho_x \cdot t_x}{\rho_{H_2O} \cdot t_{H_2O}}$$

Where ρ_x and ρ_{H_2O} are the densities of the tested samples and water and η_{H_2O} is the viscosity coefficient of water at 20 °C (Atkins, 1990).

Chemical analysis: The Soxhlet-Henkel method was used to determine the acidity by titrating the sample with 0.25 N NaOH, using 2% phenolphthalein as an indicator until a pale pink color. Acidity is also expressed as % of lactic acid, where each Sokhlet-Henkel degree is equivalent to 0.0225% of lactic acid (Teichert et al., 2020). Proteins, fat, SNF, lactose, and minerals content were determined by milk analyser *LactoStar*. All measurements were performed in triplicate. Results are represented mean values of three independent measurements ± standard deviation (SD).

Results and discussion

The aim of this study was to compare selected physico-chemical analyses of different milk analogues with purchased cow's milk (Table 1). Almond, hazelnut, quinoa, buckwheat, and rice extracts were prepared as milk analogues. Compared to cow's milk, all PBDs had lower values for protein, SNF, lactose, minerals, pH, and conductivity. The highest protein content in PBDs was found in almond and hazelnut extracts at 2.93 and 2.49%, respectively. The highest fat content was obtained in the hazelnut extract (6.52%). This is to be expected as hazelnut is a good source of fatty acids, especially monounsaturated fatty acids, and fat-soluble bioactive compounds (tocopherol, phytosterols) (Wani et al., 2020). As expected, the lactose content is highest in cow's milk (4.61%).

In addition, the results showed a higher conductivity of cow's milk than PBDs. The major contribution to conductivity is made by lactic salts, some of which are dissolved as ions, while others are in equilibrium with various species associated with casein micelles or other proteins, depending on temperature and pH, and their contribution to conductivity is difficult to determine (Henningsson et al., 2014).

Lower density values in PBDs compared to cow's milk were expected due to higher proportion of water in plant-based extracts.

The highest percentage of minerals was found in cow's milk, but when comparing milk analogues, a higher percentage was found in almond and hazelnut extracts than in buckwheat, quinoa, and rice extracts.

Table 1. Selected chemical and physical properties of cow's milk and plant extracts (rice, quinoa, buckwheat, almond and hazelnut)

Parameters	Raw Cow's milk	Rice extract	Quinoa extract	Buckwheat extract	Almond extract	Hazelnut extract
Proteins (%)	3.14±0.02	0.72±0.02	1.11±0.01	1.04±0.02	2.93±0.02	2.49±0.02
Fat (%)	3.59±0.02	0.43±0.02	0.12±0.01	0.09±0.02	2.03±0.02	6.52±0.01
SNF (%)	8.57±0.02	1.98±0.02	2.92±0.02	2.82±0.02	7.82±0.01	6.51±0.01
Lactose (%)	4.61±0.02	1.06±0.02	1.63±0.02	1.53±0.02	4.29±0.02	3.50±0.02
Minerals (%)	0.79±0.02	0.22±0.02	0.23±0.02	0.27±0.02	0.45±0.01	0.47±0.02
Acidity (°SH)	7.51±0.02	4.25±0.02	7.74±0.01	4.26±0.01	7.23±0.02	7.50±0.02
Lactic acid (%)	0.17±0.01	0.10±0.01	0.17±0.01	0.10±0.01	0.16±0.01	0.17±0.01
pH	6.15±0.04	5.95±0.03	5.80±0.04	6.03±0.04	5.61±0.03	5.50±0.03
Conductivity (mS)	6.29±0.05	3.07±0.02	5.52±0.03	3.82±0.03	4.74±0.02	1.01±0.02
Density (g/cm^3) at 20 °C	1.030±0.013	1.008±0.010	1.020±0.016	1.020±0.11	1.020±0.012	1.010±0.010
Viscosity (Pa s) at 20°C	1.815±0.022	0.968±0.02	1.121±0.024	3.957±0.032	1.288±0.024	1.606±0.021

Results represent mean values ± standard deviation (SD) of three independent measurements.

The extracts of all PBDs (except buckwheat extract) had a lower viscosity than cow's milk. The buckwheat extract had the highest viscosity. This could be related to the richness of plant fibers, which can cause the formation of large amounts of saponins during ultrasonic extraction. Saponins as a special group of glycosides that easily form foam due to the presence of sugars and triterpenes or steroid compounds and cause high viscosity of buckwheat extract due to pronounced intermolecular interactions.

In terms of acidity (°SH and lactic acid %), the lowest values were found in buckwheat and rice extracts, while cow's milk, almond, hazelnut, and quinoa extracts showed similar values.

Conclusion

The analysis of the tested parameters (proteins, SNF, lactose, minerals, acidity, lactic acid, pH, and viscosity) shows that almond and hazelnut extracts have similar or slightly lower values than cow's milk and have the highest nutritional value of the tested PBDs.

Acknowledgement

This study was supported by the Ministry of Science, Technological Development and Innovation, Republic of Serbia, contract No. 451-03-66/2024-03/200088.

References

Antunes I.C., Bexiga R., Pinto C., Roseiro L.C., Quaresma M.A.G. (2023). Cow's Milk in Human Nutrition and the Emergence of Plant-Based Milk Alternatives. Foods. 12: 99.

Atkins P. (1990). Physical Chemistry, Freeman W.H. and Company, New York.

Beacom E, Bogue J, Repar L. (2021). Market-oriented development of plant-based food and beverage products: a usage segmentation approach. Journal of Food Products Marketing. 27: 204–22.

Collard K.M., McCormick D.P. (2021). A Nutritional Comparison of Cow's Milk and Alternative Milk Products. Academic Pediatrics. 21: 1067–1069.

Comerford K.B., Miller G.D., Boileau A.C., Masiello Schuette S.N., Giddens J.C., Brown K.A. (2021). Global review of dairy recommendations in food-based dietary guidelines. Frontiers in Nutrition. 8: 671999.

Foroutan A., Guo A.C., Vazquez-Fresno R., Lipfert M., Zhang L., Zheng J., Badran H., Budinski Z., Mandal R., Ametaj B.N. (2019). Chemical composition of commercial cow's milk. Journal of Agricultural and Food Chemistry. 67: 4897–4914.

Fox P.F., Uniacke-Lowe T., McSweeney P.L.H., O'Mahony J.A. (2015). Dairy Chemistry and Biochemistry. Springer International Publishing: Cham, Switzerland.

Henningsson M., Östergren K., Dejmek P. (2014). The Electrical Conductivity of Milk—The Effect of Dilution and Temperature. International Journal of Food Properties. 8: 15–22.

Khan I.T., Nadeem M., Imran M., Ayaz M., Ajmal M., Ellahi M.Y., Khalique A. (2017). Antioxidant capacity and fatty acids characterization of heat-treated cow and buffalo milk. Lipids in Health and Disease. 16: 163.

Leduc A., Souchet S., Gele M., Le Provost F., Boutinaud M., Pascottini O., Carvalho M., Schyndel S., Ticiani E., Spricigo J. (2021). Effect of feed restriction on dairy cow milk production. Journal of Animal Science. 99: 1–12.

Mäkinen O.E., Uniacke-Lowe T., O'Mahony J.A., Arendt E.K. (2015). Physicochemical and acid gelation properties of commercial UHT-treated plant-based milk substitutes and lactose free bovine milk. Food Chemistry. 168: 630–638.

McCarthy KS, Parker M, Ameerally A, Drake SL, Drake MA. (2017). Drivers of choice for fluid milk versus plant-based alternatives: What are consumer perceptions of fluid milk? Journal of Dairy Science. 100: 6125–38.

Milovanović V., Petrović M., Kurćubić V., Petković M., Miletić N., Đurović I. (2023). Comparison of cow's milk with plant-based milk alternatives: selected chemical and physical analysis. Published in *1st International Symposium On Biotechnology*, Milošević T. (ed.), 563–569, Faculty of Agronomy Čačak, Country: Serbia.

Obermayer-Pietsch B.M., Bonelli C.M., Walter D.E., Kuhn R.J., Fahrleitner-Pammer A., Berghold A., Goessler W., Stepan V., Dobnig H., Leb G., Renner W. (2014). Genetic predisposition for adult lactose intolerance and relation to diet, bone density, and bone fractures. Journal of Bone and Mineral Research. 19: 42–7.

Teichert J., Cais-Sokolińska D., Danków R., Pikul J., Chudy S., Bierzuńska P., Kaczyński Ł.K. (2020). Color Stability of Fermented Mare's Milk and a Fermented Beverage from Cow's Milk Adapted to Mare's Milk Composition. Foods. 9: 217.

Vallath A., Shanmugam A., Rawson A. (2022). Prospects of future pulse milk variants from other healthier pulses - As an alternative to soy milk. Trends in Food Science and Technology. 124: 51-62.

Wani I.A., Ayoub A., Bhat N.A., Dar A.H., Gull A. (2020). Hazelnut. Published in *Antioxidants in Vegetables and Nuts - Properties and Health Benefits*, Nayik G.A., Gull A. (eds), pp. 559–572. Singapore: Springer.