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COMPARISON OF COW'S MILK WITH PLANT-BASED MILK ALTERNATIVES: SELECTED CHEMICAL AND PHYSICAL ANALYSIS

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Abstract: The aim of this paper is to make a chemical and physical comparison of cow's milk with plant-based milk alternatives. Selected chemical and physical parameters of animal milk (raw and pasteurized cow's milk) and plant based milk (almond and soy milk) were done. The titratable acidity, pH, conductivity, viscosity and density were measured by using standardized techniques. Additional parameters such as proteins, fat, (solids-not-fat) SNF, and lactose were determined by milk analyser and compared. The results showed that plant-based milks contain low values of proteins, fat, SNF and significantly lower acidity in comparison with cow's milk.

Keywords: raw cow's milk, pasteurized cow's milk, soy milk, almond milk

Introduction

Milk is one of the most frequently consumed foods due to its key role in nourishment and hydration. Cow's milk has been the subject of detailed chemical or nutrient analyses for many years. These include numerous studies on milk proteins, fats, carbohydrates, vitamins, and minerals (Foroutan et al., 2019). At the macronutrient level, cow's milk is composed of water (85-87%), fats (3.8-5.5%), carbohydrates (5%), and proteins (2.9-3.5%). At a micronutrient level, cow's milk contains various bioactive compounds including vitamins, minerals, organic acids, biogenic amines, oligosaccharides, nucleotides, and immunoglobulins (Fox et al., 2015).

Functional beverages have been related to several of health benefits, thus, alternatives to bovine milk beverages are in expansion, primarily made from plant sources such as soy, almond, coconut, rice, and nuts (Vallath et al, 2022). Due to health consequences or because of lifestyle choices (flexitarian, vegetarian, and vegan lifestyles), consumer demand for cow's milk alternatives

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has increased, leading to a bigger market share of plant-based milks (PBM) (Antunes et al., 2023). The organisation of the European single market for agricultural products (Regulation (EU) 1308/2013, also known as the CMO) defines „milk products" as products that are exclusively derived from milk, where "milk" presents "mammary secretion obtained from one or more milkings". The CMO specifies that dairy terms such as milk, butter, and yoghurt are completely reserved for milk and milk products. Dairy alternative products therefore cannot be referred to with dairy-associated names. For example, soy-based drinks are not allowed to be called 'soy milk' in the EU, as the product is not mammary secretion and this term is described on the list of exceptions under Commission Decision 2010/791/EU (Leialohilani, 2020).

PBM are completely free from animal-based ingredients and lack certain components associated with mammalian milk such as cholesterol, saturated fatty acids, antigens and lactose while on the same time being the good source of non allergic proteins, minerals, essential fatty acids etc., making it suitable as dairy free alternative (Das et al., 2012). PBM present fluids derived from maceration of plant material (legumes, nuts, or cereals) soaked in water and homogenisated to a size range of 5-20 μm (Kundu et al., 2018).

In general classification there are five categories of the PBM alternatives:
(1) Cereal based (Rice milk, Oat milk, Corn milk, Spelt milk); (2) Pseudo-cereal based (Quinoa milk, Amaranth milk, Teff milk); (3) Nut based (Almond milk, Coconut milk, Hazelnut milk, Pistachio milk, Walnut milk); (4) Legume based (Soy milk, Peanut milk, Lupin milk, Cowpea milk); (5) Seed based (Sesame milk, Sunflower milk, Flax milk, Hemp milk) (Sethi et al., 2016; Pointke et al., 2022).
Soy milk and almond milk are rich creamy white liquids which display similarities to cow's milk in appearance and consistency (Kundu et al., 2018).

Soy milk presents healthy food drink containing high amounts of protein, iron, unsaturated fatty acids, and niacin, but low amounts of fat, carbohydrates, and calcium comparing with cow's milk. Additionally, soy milk has high concentration of fosfatidylcholine and vitamins as well as isoflavones which are potent antioxidants (Mazumder et al., 2016).

Compared to other PBM, almond milk is naturally a rich source of vitamins, especially vitamin E which presents an esential vitamin and need to be supplied through diet or supplements (Sethi et al., 2016). Almond milk is rich source of nutrients dense lower calories than soy and cow's milk. Its nutritional benefits promote cardiovascular health and reducing of mineral deficiencies especially iron and zinc (Yetunde et al., 2015).

Materials and methods

Milk sample collection: Commercially available PBM were compared to cow's milk (raw and pasteurized form). Almond milk and soy milk were purchased from a local market. Raw cow's milk was purchased from the farmer.
Cow's milk was analysed in raw and pasteurized form. Pasteurization was done by heating raw milk at 60 °C in 30 min.

Chemical analysis: Proteins, fat, SNF, and lactose content were determined by milk analyser Julie C8 automatic™ Scope Electric. The acidity of milk was determined by Soxhlet-Henkel method, titrating the sampe with standardized 0.25 N NaOH, using 2% phenolphthalein as the indicator, giving an end-point of a faint pink color. Results are presented in Soxlet Henkel degrees (°SH). The acidity was also expressed as % of lactic acid - each degree Soxhlet-Henkel is equivalent to 0.0225% lactic acid in the milk (Teichert et al., 2020).

Physical analysis: The pH and conductivity of milk samples were determined by CyberScan CON 510-portable conductivity meter. Viscosity was determined by Ostwald's viscometer at 20 °C. The time in seconds was converted into dynamic viscosity by 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 densities of examined samples and water and t_{H_2O} is the coefficient of viscosity of water at 20 °C (Atkins, 1990). Density was determined by lactodensimeter at 20 °C. All measurements were performed in triplicate. Results are represented mean values of three independent measurements ± standard deviation (SD).

Results and discussion

In order to compare PBM with cow's milk, selected chemical and physical analysis were performed, Table 1. Almond and soy milk were selected as PBM alternatives as the most commonly used by consumers, and cow's milk was analysed in raw and pasteurized form. Pasteurization of milk maintains the content of protein and lactose similar to raw milk and slightly changes the composition of milk, decreasing total fat and total solids (Pestana et al., 2015). Our results showed that pasteurization of milk did not result in significant changes of the examined parameters except in the case of fat content which decreased after pasteurization (5.58% in raw cow's milk and 3.57% in pasteurized milk), Table 1. Comparing PBM, soy milk contains a higher content of proteins, fat, and SNF which is in agreement with literature data (Collard et al., 2020). As it is expected and in accordance to literature (Sethi et al., 2016), cow's milk is ahead of PBM when it comes to the amount of protein, fat, SNF and, lactose, Table 1.

Table 1. Selected chemical and physical characteristic of Cow's Milk, Almond and Soy milk

Parameters	Raw Cow's milk	Pasteurized Cow's milk	Almond milk	Soy milk
Proteins (%)	2.81±0.06	3.19±0.08	0.08±0.01	1.83±0.01
Fat (%)	5.58±0.09	3.57±0.06	0.67±0.03	1.42±0.01
SNF (%)	7.66±0.16	8.70±0.22	0.21±0.02	4.98±0.02
Lactose (%)	4.21±0.08	4.78±0.13	0.11±0.01	2.74±0.01
Acidity (°SH)	7.88±0.18	8.63±0.18	0.50±0.01	2.38±0.18
Lactic acid (%)	0.18±0.01	0.19±0.01	0.01±0.01	0.05±0.01
pH	6.63±0.04	6.73±0.04	8.23±0.03	8.27±0.04
Conductivity (mS)	3.27±0.04	3.49±0.05	1.22±0.02	1.95±0.07
Density (g/cm^3) at 20 °C	1.029±0.012	1.026±0.021	1.009±0.012	1.019±0.013
Viscosity (Pa s) at 20°C	1.704±0.022	1.725±0.024	4.260±0.021	2.000±0.032

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

By comparing the acidity of milk (°SH and lactic acid %), higher values were observed in cow's milk than in PBM and that is expected due to the presence of lactic acid. This is also confirmed by the value for pH, which is lower in cow's milk samples. The results showed higher conductivity of cow's milk than PBM. The biggest contribution to conductivity comes from milk salts which some are dissolved as ions, while others, depending on temperature and pH, are in equilibrium with different species associated with casein micelles or other proteins and their contribution to conductivity is difficult to determine (Henningsson et al., 2014). Lower values for density in PBM compared to cow's milk were expected considering the lower percentage of fat, protein, and SNF, and therefore a higher percentage of water.

From the value for viscosity, it can be concluded that PBM have a higher viscosity due to pronounced force of internal friction between the liquid layers which is in agreement with literature data (Mäkinen, 2015). The highest viscosity is found in almond milk, which is attributed to the lowest content of fat, protein and SNF, which leads to increase in the forces of internal friction between polar molecules of water.

Conclusion

PBM present excellent alternatives for cow's milk especially in case of cow's milk allergy, lactose intolerance, calorie concern, hypercholesterolemia, and diabetes. In addition, PBM is an excellent choice for food preparation during fasting.

The results of this study show that PBM alternatives contain low values of proteins, fat, SNF and significantly lower acidity in comparison with cow's milk.

This study is definitely not the final word on the chemical and physical composition of cow's milk and PBM alternatives. In the future, testing of a larger number of samples, additional physical and chemical analyses, as well as sensory evaluation are planned.

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