

COMPARISON OF PROPERTIES OF PLANT-BASED MILK AND COW'S MILK**I. Moroz, V. Shemet, I. Dudarev, O. Hulai***Lutsk National Technical University***Key words:**

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Corresponding author:

I. Dudarev
E-mail:
i_dudarev@ukr.net

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ABSTRACT

Consumers are increasingly choosing foods that contain plant-based dairy analogues that are affordable and have high nutritional value, including macro and micronutrients and vitamins. Plant-based milk mimic the taste and consistency of cow's milk. Plant-based milk contain no hormones or antibiotics compared to animal milk. Physical, chemical and sensory properties of plant-based milk (soy, rice-almond, rice-coconut, and oat) available on the Ukrainian market were determined and compared with those of local cow's milk. Plant-based milk was an opaque homogeneous liquid of beige color with different tinting and it had a pleasant sweet taste with an aftertaste of raw materials. Plant-based milk had an appearance and consistency similar to cow's milk. Titratable acidity of plant-based milk did not exceed 21 °T. Titratable acidity of cow's milk was 16—18 °T. Dry matter content of plant-based milks was in the range of 8.73—9.83%. Dry matter content of cow's milk was 11.63—12.52%. Density of plant-based milk was in the range of 1027—1032 kg/m³. Density of cow's milk was 1028—1029 kg/m³. Protein content of plant-based milk was 2.31—5.12 g/100 ml. Fat content of plant-based milk was 1.5—3.0 g/100 ml. Carbohydrate content of plant-based milk was 2.53—8.01 g/100 ml. In cow's milk, the protein, fat and carbohydrate contents were 3.34—3.63 g/100 ml, 2.4—2.5 g/100 ml and 4.72—4.74 g/100 ml, respectively. Caloric content of plant-based milk was 46.2—64.2 kcal/100 ml. In plant-based milk, concentration of Ca²⁺ ions was 682—1058 mg/l and concentration of Mg²⁺ ions was 96—140 mg/l, which was lower than in cow's milk. Plant-based milks are not full substitutes for cow's milk, and their recipe composition needs to be balanced to provide the human body with the necessary nutrients.

ПОРІВНЯННЯ ВЛАСТИВОСТЕЙ МОЛОКА НА РОСЛИННІЙ ОСНОВІ З КОРОВ'ЯЧИМ

І. А. Мороз, В. Я. Шемет, І. М. Дударєв, О. І. Гулай,
Луцький національний технічний університет

Споживачі все частіше вибирають продукти харчування, що містять аналоги молочних продуктів рослинного походження, які доступні за ціною та мають високий вміст поживних речовин. Молоко на рослинній основі імітує смак і консистенцію коров'ячого молока. Порівняно з коров'ячим молоком молоко на рослинній основі не містить гормонів та антибіотиків.

У статті визначено фізико-хімічні й органолептичні властивості молока на рослинній основі (соевого, рисово-мигдального, рисово-кокосового та вівсяного), яке представлено на ринку України, та порівняно його властивості з коров'ячим молоком. Досліджено, що молоко на рослинній основі — це непрозора однорідна рідина бежевого кольору з приємним солодким смаком. Молоко на рослинній основі за зовнішнім виглядом і консистенцією подібне до коров'ячого. Титрована кислотність молока на рослинній основі не перевищувала 21 °Т, а коров'ячого — 16—18 °Т. Вміст сухих речовин у молоці на рослинній основі коливався в межах 8,73—9,83%. Вміст сухих речовин у коров'ячому молоці — 11,63—12,52%. Густина молока на рослинній основі — 1027—1032 кг/м³, а коров'ячого — 1028—1029 кг/м³. Вміст білка в молоці на рослинній основі — 2,31—5,12 г/100 мл. Жирність молока на рослинній основі — 1,5—3,0 г/100 мл, а вміст вуглеводів — 2,53—8,01 г/100 мл. Вміст білків, жиру та вуглеводів у коров'ячому молоці, відповідно, 3,34—3,63 г/100 мл, 2,4—2,5 г/100 мл та 4,72—4,74 г/100 мл. Калорійність молока на рослинній основі — 46,2—64,2 ккал/100 мл. У молоці на рослинній основі концентрація іонів Ca²⁺ 682—1058 мг/л, а концентрація іонів Mg²⁺ — 96—140 мг/л, що менше ніж у коров'ячому молоці. Молоко на рослинній основі не є повноцінною заміною коров'ячого, тому його рецептурний склад повинен бути збалансованим, щоб забезпечити організм людини необхідними поживними речовинами.

Ключові слова: вівсяне молоко, рисово-мигдальне молоко, рисово-кокосове молоко, соєве молоко, напій на рослинній основі.

Formulation of the problem. Cow's milk is among the most important foods in the human diet (Lambrini et al., 2021). It is an aqueous solution of lactose, inorganic and organic salts and numerous compounds, which contains whey proteins dissolved at the molecular level, caseins dispersed in large sizes (50—500 nm), colloidal aggregates (micelles) and lipids emulsified in the form of large (1—20 μm) globules (Fox, 2008). The main macronutrients of cow's milk are water 85—87%, fat 3.8—5.5%, carbohydrates 5% and proteins 2.9—3.5% (Connolly, Yin, & Brennan, 2023). Cow's milk contains various biologically active compounds, including vitamins, minerals, organic acids, biogenic amines, oligosaccharides, nucleotides, and immunoglobulins (Milovanović et al., 2023).

Physicochemical and nutritional properties of cow's milk have been studied in detail (Bahebeck et al., 2024). Recommendations for the consumption of milk or milk products

to meet the nutritional needs of people of different ages are developed (Dror, & Allen, 2014). However, there is a steadily increasing trend of diagnosed food intolerance to animal milk and food allergy, especially among school children (Tóth et al., 2021). Thus, the problem of replacing milk with an alternative plant-based product is relevant. Plant-based milk, obtained from various sources such as nut, soy, almond, coconut, oat, rice, is attracting more and more attention.

Analysis of recent research and publications. Choosing a beverage, consumers consider factors such as cost, health benefits and the availability of nutrients and bioactive compounds, including antioxidants, probiotics, proteins, unsaturated fatty acids, minerals and vitamins (Tolun, & Altintas, 2019). Beverages made from plant-based product contain natural proteins, lipids, lecithin, dietary fiber, minerals, vitamins. The composition of beverages varies depending on the plant raw material. Plant-based milk is often low in protein and is fortified with varying amounts of calcium, and vitamins A and D (Drewnowski, Henry, & Dwyer, 2021). The use of the term "plant-based milk" is controversial. In Canada, plant-based substitutes of dairy drinks are referred to as "soft drinks" rather than "milk". The use of the term "milk" in the labeling of plant-based drinks is quite acceptable in the USA (e. g., "oat milk") (Musa-Veloso, & Juana, 2020).

Plant-based milk has the same appearance as cow's milk, and it is a suspension of dissolved and crushed plant material in water. Extraction of plant material in water and separation of the liquid are the main processes used in the production of plant-based milk. Homogenization and heat treatment are used to improve the suspension and microbial stability of commercial products (Mäkinen, Wanhalinna, Zannini, & Arendt, 2016). Non-thermal treatments, such as ultra-high temperature treatment, ultra-high pressure homogenization, pulsed electric field treatment, are also used for this purpose. These techniques provide increased shelf life, emulsion stability, improved nutritional value, and sensory acceptability of the product (Sethi, Tyagi, & Anurag, 2016). Plant-based milk is usually subjected to fermentation, which increases the activity of bioactive compounds, improves product quality, and also increases the bioavailability of minerals (Babolanimogadam, Gandomi, Akhondzadeh Basti, & Taherzadeh, 2022).

The nutritional content of foods depends on the plant raw materials used, how they are processed and how the product is fortified (Paul, Kumar, Kumar, & Sharma, 2020; Silva, Silva, & Ribeiro, 2020). Legumes are a source of essential mono- and polyunsaturated fatty acids, minerals (Fe^{2+} , Zn^{2+} , Mg^{2+}) and phytoestrogens (isoflavones). However, the soy protein contained in soy milk is an allergen. An alternative to soy milk are beverages made from chickpeas, lentils, lupins, and peas. These legumes are rich in protein, carbohydrates, dietary fiber, potassium, magnesium, zinc, B vitamins (Vallath, Shanmugam, & Rawson, 2022).

Among the range of plant-based milk, oat milk is in high demand due to its mild texture and taste. The use of oats in the production of plant-based milk ensures that the milk is enriched with nutrients and phytochemicals (Cui, Jia, Zhao, Hou, & Zhou, 2023). Cereal contains β -glucans, which help reduce cholesterol levels and improve the sensory properties of the drinks (Tangyu, Muller, Bolten, & Wittmann, 2019). Oat milk contains 34.03% carbohydrate, 0.966% protein, 0.36% fat, 3.2% fiber, and approximately 0.54% β -glucan (Syed, Gadhe, & Shaikh, 2020).

Plant-based milk is widely touted as healthy and beneficial, but understanding the long-term effects of consuming this beverage requires extensive research. There are a

number of problems associated with obtaining complete plant-based milk substitutes. Consumers consider these alternatives as direct substitutes for cow's milk, which is not true (Vanga, & Raghavan, 2018). Researchers believe that dairy alternatives differ from cow's milk in sensory properties, stability and nutrition content. Low biological value of proteins, insufficient amount of vitamins and low bioavailability of essential minerals are typical for most plant-based milk. Replacing cow's milk with plant-based milk can lead to deficiencies in calcium and zinc.

There is also a social aspect to the growth of the plant-based milk market. Plant-based milk has become a low-cost alternative for developing countries and places where the supply of cow's milk is insufficient (Sethi, Tyagi, & Anurag, 2016). Thus, alternative dairy products from various Ukrainian producers are gaining popularity and distribution.

The purpose of the research was to compare the properties of plant-based milk with cow's milk.

Materials and methods. *Sample preparation.* Samples of soy milk (SM), rice-coconut milk (RCM), rice-almond milk (RAM) and oat milk (OM) from local market (Lutsk, Ukraine) were examined. Cow's milk from local market (CMM) and farm (CMF) (Volyn region, Ukraine) were also examined. Plant-based milk and cow's milk samples were collected according to (Imran, Khan, Hassan, & Khan, 2008).

Physical and chemical properties measurements. Dry matter content of plant-based milk and cow's milk was determined by the gravimetric method by drying the samples to a constant mass for 2.5 h at a temperature of 102 ± 2 °C (Lim et al., 2023).

Titrate acidity of plant-based milk and cow's milk was determined by the titrimetric method (Tomovska, Gjorgievski, & Makarijoski, 2016). The active acidity (pH) of plant-based milk and cow's milk was determined by the potentiometric titration (Tomovska, Gjorgievski, & Makarijoski, 2016). Density of the milk samples was determined by the pycnometer method (Parmar et al., 2020).

Milk protein content was determined by spectrophotometric method according to the technique (Bhavya Sri, Hema, Anila, & Sumakanth Mogili, 2023), which is based on the formation of a colored product between milk proteins and concentrated nitric acid and subsequent determination of the optical density of the system. The optical density of the samples was measured using an AR-120 photoelectric colorimeter at a wavelength of 420 nm.

Total sugar content was determined by refractometry according to the method described in (McDonald et al., 2013). Fat content of the milk samples was determined by the Gerber method (Kleyn et al., 2001). In cow's milk and plant-based milk, content of calcium and magnesium was determined by the titrimetric method (Masotti, Cattaneo, Stuknytė, Pica, & De Noni, 2020).

Caloric content calculation. Caloric content of cow's milk or plant-based milk was calculated by Equation (1) (Capuano, Oliviero, Fogliano, & Pellegrini, 2018):

$$E = k_p P + k_f F + k_c C, \quad (1)$$

where: E — caloric content (kcal/100 ml); k_p, k_f, k_c — caloric content per 1 g of protein, fat and carbohydrates ($k_p = 4$ kcal; $k_f = 9$ kcal; $k_c = 3.75$ kcal) (kcal); P, F, C — content of protein, fat and carbohydrates per 100 ml of the milks (g/100 ml).

Sensory analysis. The plant-based milk samples were successively presented to the experts. All experts were food technology professionals who had training in sensory analysis. The expert evaluation of the sensory properties (appearance, taste, smell, color,

consistency) of the plant-based milk was performed in accordance with (Gomes et al., 2013) according to the scale: 5 points — very good quality; 4 points — good quality; 3 points — sufficient quality; 2 points — insufficient quality; 1 point — poor quality. Based on the results of the expert evaluation, the sensory profiles of different types of plant-based milk were created.

Quality assessment method. The weighting coefficients of the sensory properties of plant-based milk were determined by the ranking method based on the results of a survey of experts (Pudovkin, 2021). All experts were food technology professionals who had training in sensory analysis. The quality index of plant-based milk was calculated by Equation (2):

$$Q = \sum_{i=1}^n m_i q_i, \quad (2)$$

where: m_i — the weighting coefficient of the sensory properties of the plant-based milks; q_i — the average value of the sensory property (points).

Statistical analysis and calculations. All analyses were performed in triplicate and data reported as mean \pm standard deviation (SD). The level of significance was set at $P < 0.05$. Statistical analysis and calculations were conducted using the Mathcad 14 software.

Results and discussion. *Physical and chemical properties.* Physical and chemical properties of plant-based milk and cow's milk are presented in Table 1—2. Active acidity of the plant-based milk and cow's milk ranged from 6.65 (cow's milk from local market) to 7.21 (rice-coconut milk). Active acidity of different types of plant-based milk probably did not differ from those of cow's milk (Table 1). The results of measuring the pH values of plant-based milk (almond, oat) obtained by Jemaa, Gamra, Falleh, Ksouri, & Beji (2021) show that the pH of beverages is close to neutrality.

Table 1. Active and titratable acidity, dry matter and density of plant-based milk and cow's milk

Plant-based milk and cow's milk	Active acidity (pH)	Titratable acidity, °T	Dry matter, %	Density, kg/m ³
Oat milk	7.16±0.01	6.60±0.01	9.18±0.05	1027.5±0.8
Soy milk	6.82±0.01	21.00±0.01	8.73±0.04	1030.0±0.7
Rice-almond milk	7.13±0.02	4.30±0.01	9.36±0.06	1028.0±0.7
Rice-coconut milk	7.21±0.02	3.30±0.01	9.83±0.05	1032.0±0.7
Cow's milk from local market	6.65±0.01	18.00±0.02	11.63±0.06	1028.0±0.9
Cow's milk from local farm	6.78±0.01	16.00±0.02	12.52±0.06	1029.0±0.9

Table 2. Calcium and magnesium ions content of plant-based milk and cow's milk

Plant-based milk and cow's milk	C (Ca ²⁺), mg/l	C (Mg ²⁺), mg/l
Oat milk	940.0±0.6	104.0±0.3
Soy milk	1058.0±0.6	140.0±0.3
Rice-almond milk	682.0±0.5	96.0±0.4
Rice-coconut milk	944.0±0.6	124.0±0.5
Cow's milk from local market	1354.0±0.7	164.0±0.4
Cow's milk from local farm	1414.0±0.4	188.0±0.6

Titratable acidity of cow's milk, which was 16—18 °T (Table 1), corresponded to the standard acidity values according to ISO 6091:2010. Titratable acidity of oat milk, rice-almond milk and rice-coconut milk was 6.6±0.01 °T, 4.3±0.01 °T and 3.3±0.01 °T,

respectively (Table 1). This was significantly lower than titratable acidity of cow's milk. However, titratable acidity of soy milk was 21 °T. This difference was due to the fact that the titratable acidity of cow's milk was determined by a complex of natural factors (content of fats, fatty acids, bacterial flora), which vary slightly depending on the composition of milk, storage and processing conditions. In plant-based milk, the complex of these factors is artificially created according to the milk recipe, therefore the titratable acidity of plant-based milk can differ significantly.

Density of plant-based milk and cow's milk was within 1027.5—1032.0 kg/m³ (Table 2). Dry matter in plant-based milk was lower (8.73—9.83%) than in cow's milk (11.63—12.52%) (Table 1). This was due to the lower content of protein, fats and, accordingly, dry matter in plant raw materials used for the production of plant-based milk. According to Walther et al. (2022), the mean values of dry matter for different plant-based milk were ranged as follows: almond 54.6 g/kg; coconut 43.0 g/kg; oat 90.3 g/kg; rice 118.4 g/kg; soy 84.2 g/kg.

Content of calcium and magnesium ions in plant-based milk was 682—1058 mg/l and 96—140 mg/l, respectively (Table 2). Among the different types of plant-based milk, the highest calcium content was in soy milk 1058±0.6 mg/l, and the lowest content was in rice-almond milk 682.0±0.5 mg/l. The highest magnesium content was also found in soy milk 140.0±0.3 mg/l. Content of calcium and magnesium ions in cow's milk was 1354—1414 mg/l and 164—188 mg/l, respectively (Table 2). According to Haas, Schnepfs, Pichler, & Meixner (2019), soy milk contains less calcium than cow's milk. According to Walther et al. (2022), the mean values of magnesium content for different plant-based milk were ranged as follows: almond 95.0 mg/kg; coconut 59.0 mg/kg; oat 42.0 mg/kg; rice 68.0 mg/kg; soy 200.0 mg/kg.

Nutritional value of plant-based milk and cow's milk is presented in Table 3. Protein content of cow's milk was 3.34—3.63 g/100 ml (Table 4). In the samples of plant-based milk (except soy milk), the protein content was lower than for cow's milk, ranging from 2.31 g/100 ml to 2.71 g/100 ml. Protein content of soy milk was 5.12 g/100 ml, which was due to the high content of plant-based protein in the soybeans from which the milk was made. According to Chalupa-Krebdak, Long, & Bohrer (2018), the soy-based milk had the highest protein content among the different types of plant-based milk, ranging from 2.50 to 3.16 g/100 ml, and almond-based milk had the lowest average protein content, ranging from 0.31 to 0.59 g/100 ml.

Table 3. Nutritional value of plant-based milk and cow's milk

Plant-based milk and cow's milk	Protein, g/100 ml	Fat, g/100 ml	Carbohydrate, g/100 ml	Energy, kcal/100 ml
Oat milk	2.50±0.02	2.5±0.1	6.51±0.03	56.9
Soy milk	5.12±0.03	1.8±0.1	2.53±0.02	46.2
Rice-almond milk	2.31±0.01	1.5±0.1	8.01±0.01	52.8
Rice-coconut milk	2.71±0.01	3.0±0.2	7.03±0.03	64.2
Cow's milk from local market	3.34±0.02	2.4±0.1	4.74±0.01	52.7
Cow's milk from local farm	3.63±0.01	2.5±0.1	4.72±0.01	54.7

Fat content in cow's milk was between 2.4 and 2.5 g/100 ml. Fat content of plant-based milk depended on the composition of the beverages and ranged from 1.5 to

3.0 g/100 ml. Rice-almond milk and soy milk had the lowest fat content at 1.5 g/100 ml and 1.8 g/100 ml, respectively. The results are consistent with the conclusions of Collard, & McCormick (2021) that cow's milk is the best source of fat and protein. The studies by Kalyn, Collard, & McCormick (2021) also found that the fat content of soy and almond milk was at least half that of cow's milk.

Content of carbohydrates in all types of analyzed plant-based milk (except soy milk) was in the range of 6.5—8.0 g/100 ml, which was higher than the content of carbohydrates in cow's milk (4.7 g/100 ml). The lowest carbohydrate content was in soy milk (2.5 g/100 ml). According to Fructuoso et al. (2021), carbohydrate content in different types of plant-based milk varied widely, from 0 to 22.29 g/100 ml.

Caloric content of cow's milk from the local market and from the local farm was 52.7 kcal/100 ml and 54.7 kcal/100 ml, respectively. Among the different types of plant-based milk, rice-coconut milk had the highest caloric content (64.2 kcal/100 ml), while soy milk had the lowest (46.2 kcal/100 ml). According to Fructuoso et al. (2021), the energy value of different types of plant-based milk varied widely, from 6 to 183 kcal/100 ml, depending on the beverage ingredients.

Sensory analysis. Appearance of all types of plant-based milk was rated with high average scores of 4.6—5.0 (Figure 1a). Oat milk and soy milk received the highest average scores (5.0 points). The appearance of supermarket milk was rated lower (4.8 points) than the appearance of farm milk (4.9 points) (Figure 1b), which is not significantly different from the appearance of various types of plant-based milk. The appearance of rice-coconut milk received the lowest average score from experts (4.6 points).

Consistency of oat milk and rice-almond milk was rated the highest at 5.0 points (Figure 1a). Soy milk and rice-coconut milk were rated 4.8 and 4.6 points, respectively. It was noted that plant-based milk is an opaque homogeneous liquid. The homogeneity of the plant milk produced by the Ukrainian manufacturers was ensured by the fact that the recipe contained a stabilization system (calcium carbonate, gellan gum and maltodextrin or carrageenan or locust bean gum). Cow's milk exhibit a smooth, liquid texture with a certain degree of viscosity. The consistency of cow's milk from the local market was rated lower (4.9 points) than the consistency of farm milk (5.0 points) (Figure 1b). Thus, all types of plant-based milk were similar in appearance and consistency to cow's milk. In previous studies, plant-based soft drinks were found to have sensory properties (consistency and appearance) similar to dairy beverages (Scholz-Ahrens, Ahrens, & Bart, 2020; Fructuoso et al., 2021).

All types of plant-based milk had a pleasant sweet taste with an aftertaste of the raw materials from which they were made. In plant-based beverages, beany, almond and oat flavors were particularly noticeable. The experts rated the taste of soy milk (5.0 points) and oat milk (4.6 points) highest, while rice-almond milk and rice-coconut milk received 4 points (Figure 1a). Cow's milk scored very high for taste (4.9—5.0 points) (Figure 1b). The taste of cow's milk was described as milky and sweet.

Plant-based milk has a neutral, slightly sweet smell. However, milk containing rice had cereal smell. Smell of soy milk was rated at 4.8 points, while rice-almond and rice-coconut milks were rated at 3.8 and 3.6 points, respectively. Oat milk was rated 4.2 points for smell. Cow's milk had a slightly sweet and mostly odorless smell. The smell of cow's milk was rated higher (5.0 points) than the smell of plant-based beverages (Figure 1).

All types of plant-based milk had a uniform beige color throughout the volume with different tinting. Color of plant-based milk was evaluated with high scores of 4.4—5.0. Cow's milk from the local market and farm was pale yellow and scored 5.0 points. Hence, color, taste and smell of plant-based milk differed from those of cow's milk.

The analysis of the sensory profiles of the plant-based milk (Figure 1a) shows that oat milk and soy milk had the best sensory characteristics. However, cow's milk had better sensory characteristics than plant-based milk. Jaeger, Dupas de Matos, Fremppomaa Oduro, & Hort (2024) note that the sensory characteristics of plant-based milk vary widely depending on the raw material and fortification. Cardello, Llobell, Giacalone, Roigard, & Jaeger (2022) noted that soy-based products were found to have metallic and astringent tastes, hay-like odour, cereal-based products (oat, rice) were found to have a cereal flavour, nut-based products (almond, coconut) were characterised by nutty flavours. Inferior sensory properties of plant-based milk compared to dairy milks are a major challenge and can reduce consumer acceptance of these beverages. As a result, there is a need to improve the flavour profile of plant-based milk.

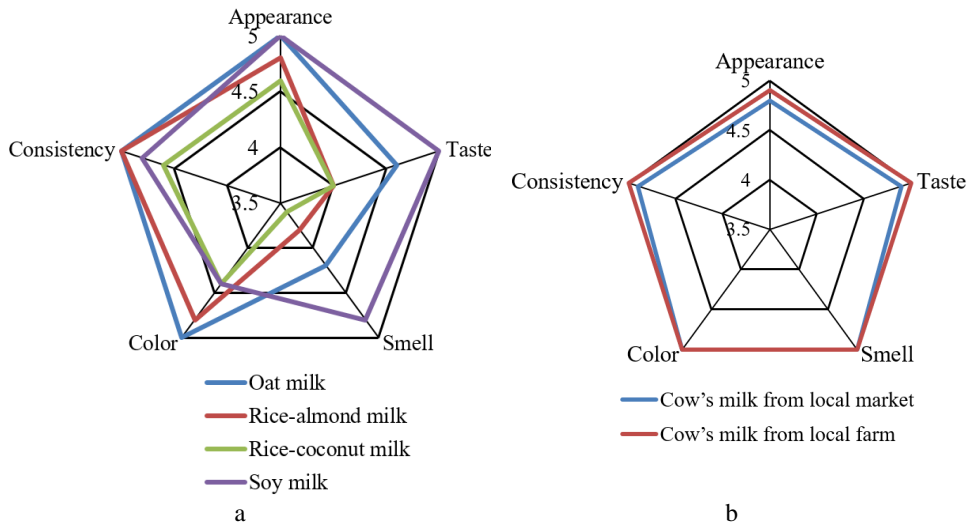


Figure 1. The sensory profiles of the different types of plant-based milk (a) and cow's milk (b) (average values of sensory indicators)

Quality assessment. Using the expert method, the weighting coefficients of sensory properties of plant-based milk and cow's milk were determined: taste — $m_1 = 0.33$; smell — $m_2 = 0.24$; appearance — $m_3 = 0.19$; color — $m_4 = 0.15$; consistency — $m_5 = 0.09$. According to experts, the taste was the most important sensory property of milks for consumers, while consistency was the least important sensory property.

In Figure 2, the calculating results of quality index of plant-based milk and cow's milk are presented. The soy milk had the highest value of the quality index, which was $Q = 4.844$. Thus, it was the most preferred beverage. The highest acceptability index for the flavor attribute was also found for the soybean beverage by Frühauf, Egea, Hernandez, & Takeuchi (2022). The rice-coconut milk (RCM) had the lowest value of the quality index, which was $Q = 4.132$. Other types of plant-based milk had the following values: oat milk (OM) — $Q = 4.676$; rice-almond milk (RAM) — $Q = 4.314$. The quality

indices of cow's milk from the local market ($Q = 4.92$) and from the farm ($Q = 4.981$) were higher than the quality indices of plant-based milks.

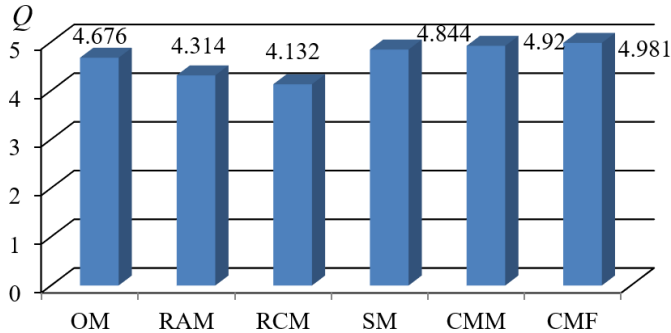


Figure 2. Quality indexes Q of the different types of plant-based milk and cow's milk

Conclusions

Active acidity (pH) of plant-based milk and cow's milk varies in the range of 6.65—7.21. In plant-based milk, titratable acidity varies within a wide range of 3.3—21.0 °T, which may be related to the recipe composition of the soft drinks. For most types of plant-based milk, titratable acidity is lower than the titratable acidity of cow's milk, which is 16—18 °T.

Density of plant-based milk and cow's milk not significantly different. However, dry matter in plant-based milk is up to 30.3% less than in cow's milk.

In plant-based milk, calcium content was found to be 25.2—49.6% lower than in cow's milk and magnesium content was found to be 25.5—41.5% lower than in cow's milk.

Nutrient and caloric content of plant-based milk depend on the recipe composition. Protein content of various types of plant-based milk, except soy milk, is lower than the protein content of cow's milk. Fat content of plant-based milk can be lower or higher than that found in cow's milk. Plant-based milk, except soy, are higher in carbohydrates than cow's milk.

Comparing plant-based milk and cow's milk according to their sensory, physical and chemical properties, it can be concluded that plant-based milk is not full-fledged substitutes for cow's milk, and its recipe composition needs to be balanced to provide the human body with the necessary nutrients.

Consistency and appearance of plant-based milk are similar to cow's milk. However, color of plant-based milk, which is beige with different tinting, is different from the color of cow's milk. Taste and smell of plant-based milk differ from cow's milk and depend on the raw materials used to make the soft drinks. Different types of plant-based milk have oat, coconut, soy, almond, and rice flavors and aromas. A comparison of the properties of different types of plant-based milk and cow's milk available on the Ukrainian market could help the consumers to make an informed decision about purchasing plant based milk beverages, taking into account their needs. In addition, the research results obtained can be used by producers to improve or develop new types of plant-based milk with improved sensory and nutritional properties.

References

- Babolanmogadam, N., Gandomi, H., Akhondzadeh Basti, A., & Taherzadeh, M. J. (2022). Nutritional, functional, and sensorial properties of oat milk produced by single and combined acid, alkaline, α -amylase, and sprouting treatments. *Food Science & Nutrition*, 11(5), 2288—2297. doi:10.1002/fsn3.3171.
- Bahebeck, P. N., Mengue, N. Y., Mohamadou, A., Noudjio, K. C., Nadjji-Nome, N., Mvondo, E. G. N., Hakoueu, F., & Etchu, K. A. (2024). Physicochemical properties of fresh cow's milk produced in the North-West Region, Cameroon (Central Africa). *Journal of Veterinary and Marine Research*, 4(1), 1—8.
- Bhavya Sri, K., Hema, B., Anila, B., & Sumakanth, M. (2023). A simple spectrophotometric method for quantification of casein in milk and milk products. *International Journal of Advanced Research*, 11(1), 1741—1745. doi:10.21474/IJAR01/16200.
- Capuano, E., Oliviero, T., Fogliano, V., & Pellegrini, N. (2018). Role of the food matrix and digestion on calculation of the actual energy content of food. *Nutrition Reviews*, 76(4), 274—289. doi:10.1093/nutrit/nux072.
- Cardello, A. V., Llobell, F., Giacalone, D., Roigard, C. M., & Jaeger, S. R. (2022). Plant-based alternatives vs dairy milk: Consumer segments and their sensory, emotional, cognitive and situational use responses to tasted products. *Food Quality and Preference*, 100, article number 104599. doi:10.1016/j.foodqual.2022.104599.
- Chalupa-Krebdak, S., Long, C. J., & Bohrer, B. M. (2018). Nutrient density and nutritional value of milk and plant-based milk alternatives. *International Dairy Journal*, 87, 84—92. doi:10.1016/j.idairyj.2018.07.018.
- Collard, K. M., & McCormick, D. P. (2021). A nutritional comparison of cow's milk and alternative milk products. *Academic Pediatrics*, 21(6), 1067—1069. doi:10.1016/j.acap.2020.12.007.
- Connolly, C., Yin, X., & Brennan, L. (2023). Impact of lactation stage on the metabolite composition of bovine milk. *Molecules*, 28(18), article number 6608. doi:10.3390/molecules28186608.
- Cui, L., Jia, Q., Zhao, J., Hou, D., & Zhou, S. (2023). A comprehensive review on oat milk: from oat nutrients and phytochemicals to its processing technologies, product features, and potential applications. *Food & Function*, 14(13), 5858—5869. doi:10.1039/d3fo00893b.
- Drewnowski, A., Henry, C. J., & Dwyer, J. T. (2021). Proposed nutrient standards for plant-based beverages intended as milk alternatives. *Frontiers in Nutrition*, 8, article number 761442. doi:10.3389/fnut.2021.761442.
- Dror, D. K., & Allen, L. H. (2014). Dairy product intake in children and adolescents in developed countries: trends, nutritional contribution, and a review of association with health outcomes. *Nutrition Reviews*, 72(2), 68—81. doi:10.1111/nure.12078.
- Fox, P. F. (2008). Milk: An overview. *Food Science and Technology*, 1, 1—54. doi:10.1016/B978-0-12-374039-7.00001-5.
- Fructuoso, I., Romão, B., Han, H., Raposo, A., Ariza-Montes, A., Araya-Castillo, L., & Puppini Zandonadi, R. (2021). An overview on nutritional aspects of plant-based beverages used as substitutes for cow's milk. *Nutrients*, 13, 2650—26800. doi:10.3390/nu13082650.
- Frühauf, V., Egea, M., Hernandez, T., & Takeuchi, K. (2022). Relationship between physicochemical and sensory characteristics of commercial plant-based beverages. *Journal of Culinary Science & Technology*, 21(6), 886—902. doi:10.1080/15428052.2021.2024470.
- Gomes, J. J. L., Duarte, A. M., Batista, A. S. M., de Figueiredo, R. M. F., de Sousa, E. P., de Souza, E. L., & de Cássia Ramos do Egypto Queiroga, R. (2013). Physicochemical and sensory properties of fermented dairy beverages made with goat's milk, cow's milk and a mixture of the two milks. *LWT — Food Science and Technology*, 54(1), 18—24. doi:10.1016/j.lwt.2013.04.022.
- Haas, R., Schnepfs, A., Pichler, A., & Meixner, O. (2019). Cow milk versus plant-based milk substitutes: a comparison of product image and motivational structure of consumption. *Sustainability*, 11(18), article number 5046. doi:10.3390/su11185046.

Imran, M., Khan, H., Hassan, S. S., & Khan, R. (2008). Physicochemical characteristics of various milk samples available in Pakistan. *Journal of Zhejiang University SCIENCE B*, 9(7), 546—551. doi:10.1631/jzus.b0820052.

Jaeger, S. R., Dupas de Matos, A., Frempomaa Oduro, A., & Hort, J. (2024). Sensory characteristics of plant-based milk alternatives: Product characterisation by consumers and drivers of liking. *Food Research International*, 180, article number 114093. doi:10.1016/j.foodres.2024.114093.

Jemaa, M. B., Gamra, R., Falleh, H., Ksouri, R., & Beji, R. S. (2021). Plant-based milk alternative: nutritional profiling, physical characterization and sensorial assessment. *Current Perspectives on Medicinal and Aromatic Plants*, 4(2), 108—120. doi:10.38093/cupmap.1037118.

Kalyn, M., Collard, D. P., & McCormick, A. (2021). Nutritional comparison of cow's milk and alternative milk products. *Academic Pediatrics*, 21(6), 1067—1069. doi:10.1016/j.acap.2020.12.007.

Kleyn, D. H., Lynch, J. M., Barbano, D. M., Bloom, M. J., Mitchell, M. W., Cooper, L. S., Cusak, E., Fick, M., Hanks, T., Heslen, M. K., Johnson, J., Kleyn, D. H., Mercer, F., Monahan, D., Peat, B., & Petit, M. (2001). Determination of fat in raw and processed milks by the Gerber method: collaborative study. *Journal of AOAC INTERNATIONAL*, 84(5), 1499—1508. doi:10.1093/jaoac/84.5.1499.

Lambrini, K., Aikaterini, F., Konstantinos, K., Christos, I., Ioanna, P. V., & Areti, T. (2021). Milk nutritional composition and its role in human health. *Journal of Pharmacy and Pharmacology*, 9(1), 8—13. doi:10.17265/2328-2150/2021.01.002.

Lim, S. H., Chin, N. L., Sulaiman, A., Tay, C. H., & Wong, T. H. (2023). Microbiological, physicochemical and nutritional properties of fresh cow milk treated with industrial high-pressure processing (HPP) during storage. *Foods*, 12(3), article number 592. doi:10.3390/foods12030592.

Masotti, F., Cattaneo, S., Stuknyté, M., Pica, V., & De Noni, I. (2020). Analytical advances in the determination of calcium in bovine milk, dairy products and milk-based infant formulas. *Trends in Food Science & Technology*, 103, 348—360. doi:10.1016/j.tifs.2020.07.013.

McDonald, H., Arpaia, M. L., Caporaso, F., Obenland, D., Were, L., Rakovski, C., & Prakash, A. (2013). Effect of gamma irradiation treatment at phytosanitary dose levels on the quality of "Lane Late" navel oranges. *Postharvest Biology and Technology*, 86, 91—99. doi:10.1016/j.postharvbio.2013.06.018.

Mäkinen, O. E., Wanhalinna, V. Z., Zannini, E., & Arendt, E. K. (2016). Foods for special dietary needs: non-dairy plant-based milk substitutes and fermented dairy-type products. *Critical Reviews in Food Science and Nutrition*, 56(3), 339—349. doi:10.1080/10408398.2012.761950.

Milovanović, V., Petrović, M., Kurčić, V., Petrović, M., Miletić, N., & Durović, I. (2023). Comparison of cow's milk with plant-based milk alternatives: selected chemical and physical analysis. *Proceedings*, 53, 517—522. doi:10.46793/SBT28.517M.

Musa-Veloso, K., & Juana, J. (2020). Regulation and labeling of plant-based beverages and simulated meat, poultry, and egg products in Canada and the United States. *Cereal Foods World*, 65(4). doi:10.1094/CFW-65-4-0044.

Paul, A. A., Kumar, S., Kumar, V., & Sharma, R. (2020). Milk analog: Plant based alternatives to conventional milk, production, potential and health concerns. *Critical Reviews in Food Science and Nutrition*, 60(18), 3005—3023. doi:10.1080/10408398.2019.1674243.

Parmar, P., Lopez-Villalobos, N., Tobin, J. T., Murphy, E., McDonagh, A., Crowley, S. V., Kelly, A. L., & Shalloo, L. (2020). The effect of compositional changes due to seasonal variation on milk density and the determination of season-based density conversion factors for use in the dairy industry. *Foods*, 9(8), article number 1004. doi:10.3390/foods9081004.

Pudovkin, O. P. (2021). Application of qualimetric methods for assessing quality of complex products. *Journal of Physics: Conference Series*, article number 1728012018. doi:10.1088/1742-6596/1728/1/012018.

Sethi, S., Tyagi, S., & Anurag, R. (2016). Plant-based milk alternatives an emerging segment of functional beverages: a review. *Journal of Food Science and Technology*, 53. doi:10.1007/s13197-016-2328-3.

Scholz-Ahrens, K. E., Ahrens, F., & Bart, Ch. A. (2020). Nutritional and health benefits of milk and milk imitations. *European Journal of Nutrition*, 59, 19—34. doi:10.1007/s00394-019-01936-3.

Silva, R. A., Silva, M. N., & Ribeiro, B. D. (2020). Health issues and technological aspects of plant-based alternative milk. *Food Research International*, 131, article number 108972. doi:10.1016/j.foodres.2019.108972.

Syed, S. J., Gadhe, K. S., & Shaikh, R. P. (2020). Studies on quality evaluation of oat milk. *Journal of Pharmacognosy and Phytochemistry*, 9(1), 2275—2277.

Tangyu, M., Muller, J., Boltzen, Ch. J., & Wittmann, Ch. (2019). Fermentation of plant-based milk alternatives for improved flavour and nutritional value. *Applied Microbiology and Biotechnology*, 103, 9263—9275. doi:10.1007/s00253-019-10175-9.

Tolun, A., & Altıntaş, Z. (2019). Medicinal properties and functional components of beverages. *Functional and Medicinal Beverages*, 11, 235—284. doi:10.1016/B978-0-12-816397-9.00007-8.

Tomovska, J., Gjorgievski, N., & Makarijoski, B. (2016). Examination of pH, titratable acidity and antioxidant activity in fermented milk. *Journal of Materials Science and Engineering*, A6(11—12), 326—333. doi:10.17265/2161-6213/2016.11-12.006.

Tóth, A. J., Kovács, A., Dunay, A., Illés, C. B., Fehér, O., & Bittsánszky, A. (2021). Catering of children with special dietary needs in school. *Carpathian Journal of Food Science and Technology*, 13(2), 84—92. doi:10.34302/crpfjst/2021.13.2.8.

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 & Technology*, 124, 51—62. doi:10.1016/j.tifs.2022.03.028.

Vanga, S. K., & Raghavan, V. (2018). How well do plant based alternatives fare nutritionally compared to cow's milk? *Journal of Food Science and Technology*, 55(1), 10—20. doi:10.1007/s13197-017-2915-y.

Walther, B., Guggisberg, D., Badertscher, R., Egger, L., Portmann, R., Dubois, S., ... Rezzi, S. (2022). Comparison of nutritional composition between plant-based drinks and cow's milk. *Frontiers in Nutrition*, 9, article number 988707. doi:10.3389/fnut.2022.988707.