Scientific Papers. Series B, Horticulture. Vol. LXVIII, No. 1, 2024
Print ISSN 2285-5653, CD-ROM ISSN 2285-5661, Online ISSN 2286-1580, ISSN-L 2285-5653

PLANT MILK - ALTERNATIVE FOR DAIRY PRODUCTS. RHEOLOGICAL CHARACTERISTICS AND NUTRITIONAL COMPOSITION

Sofia POPESCU, Ariana VELCIOV, Florina RADU, Despina BORDEAN, Antoanela COZMA, Luminița PÎRVULESCU, Lia ROTARIU, Anișoara IENCIU

University of Life Sciences „King Mihai I” from Timișoara, 119 Calea Aradului, Timișoara, Romania

Corresponding author email: sofiapopescu@yahoo.com

Abstract

The objective of this work was to evaluate the physical, chemical and rheological characteristics of vegetable milk of soybean and almond (homemade prepared, and some types of plant milk purchased from Romanian supermarkets). Vegetable milk is a colloidal solution obtained in the form of water extract from swollen and ground soybeans or other grains (rice, oats, almonds a.o.). The vegetable milk samples (soymilk and almond milk) were prepared from analyzed grains and then a set of chemical and physical characteristics of the milk were assessed. The present study paper investigated the moisture and total dry content substance (TDC), total mineral content - ash content, macronutrients content (fat, protein and carbohydrate content) for soybeans, almonds and vegetable milk samples.

Key words: *soybeans, almonds, plant milk, rheological characterization, moisture, fat, protein content.*

INTRODUCTION

Milk is the lacteal secretion obtained by the complete milking of one or more healthy milch animals", thus technically differentiating animal milk from plant milk (Fructuoso et al., 2021). Globally, cow's milk and its derivatives are consumed by over 6 billion people (Fructuoso et al., 2021), mainly due to their protein and calcium content (Fructuoso et al., 2021; Silva et al., 2019; Vanga & Raghavan, 2018).

Despite the dietary benefits offered by milk, some people present with disorders such as cow's milk allergy (CMA) and lactose intolerance (65-75% of individuals) (Fructuoso et al. 2021; Munekata et al., 2020; Vanga and Raghavan, 2018; Mäkinen et al., 2016).

Taking into account all the disorders produced by animal milk, the main alternative would be to replace it with vegetable/plant) milk. Plant milks are liquid emulsions obtained by the decomposition of plant tissues extracted in water. Plant milk is a stable emulsion of oil, water and protein (Micula et al., 2016; Bonifacio da Silva et al., 2009; Li et al., 2016). The stability of the final product and the size of the emulsion particles depend on the nature, biological properties of the raw material, decomposition and storage conditions of the raw material. To be functional, plant-based milk alternatives must be able to meet the needs of those who choose different lifestyles, to increase energy, to fight aging, fatigue, stress, promote cardiovascular health and reduce some mineral deficiencies (e.g.: iron and zinc) (Milovanovic et al., 2023; Omoni and Aluko, 2005; Kundu et al., 2018).

Plant-based drinks show variable composition on the amount of macro- and micronutrients and the presence of bioactive compounds and anti-nutritional factors (Munekata et al., 2020). These differences are due to the type of plants used for the preparation of vegetable milk. For the manufacturing process of vegetable milk, are used either legumes (e.g.: soy, chickpea), nuts/nut kernels (e.g.: almonds, cashew nuts, hazelnuts and Brazil nuts, seeds (sunflower, sesame), cereals (rice, oats) or pseudocereals (e.g. quinoa).

Increasing demand for non-dairy alternatives has been driven by concerns about dairy milk consumption such as socio-religious beliefs against the consumption of animal products, allergenicity associated with its constituents, phobia for contracting diseases and the philosophical and ethical practice of veganism (Panghal et al., 2018), The most popular plant-based milk beverages are obtained from almonds, oats, soy, cashew and coconut, or a mixture of those (Vanga and Raghavan, 2018)

An alternative to dairy products is soymilk and it has long been a traditional drink in Asia - China, Japan and other parts of this continent (Micula et al., 2016; Liu, 1997).

Soybean (*Glycine max*) is an important source of macronutrients, minerals, vitamins and many bioactive compounds (mainly isoflavones) – which are important for the health benefits offered. Bioactive compounds increase the protection against cardiovascular disease, cancer, osteoporosis, dermatologic diseases and neurodegenerative disorders (Aydar et al., 2020). Soybeans are also a source of essential monounsaturated and polyunsaturated fatty acids, including linoleic and linolenic acids, and are cholesterol-free (Karimidastjerd and Gulsunoglu Konuskan, 2021; Silva et al., 2020).

Soy milk has a lot of nutritional compounds, high digestibility and low production cost and does not contain lactose, cholesterol (Sethi et al., 2016). Because soy milk contains various proteins that can cause allergic reactions, people with cow's milk allergy may also have reactions against soy (Karimidastjerd and Gulsunoglu Konuskan, 2021; Silva et al., 2020). Due to some antinutrients, such as phytate, oxalate and saponins that form insoluble compounds as a result of the reaction with mineral cations, soy milk has a negative effect on health by decreasing the bioavailability of vitamins and minerals (Aydar et al., 2020).

The most consumed milk alternative among plant milks is almond milk. Almonds (Prunus dulcis) have become an important food for a modern, healthy lifestyle because they contain many beneficial components (Sathe et al., 2002). Almonds contain a large amount of soluble sugars, proteins, lipids, minerals, fibers and antioxidants (Silva et al., 2020).

Almond milk has a multitude of benefits such as controlling blood lipids, preventing anemia, lowering the risk of heart disease, and the antioxidant effect by protecting against free radicals. Almonds can also have a prebiotic action due to the content of arabinose that helps reduce serum cholesterol levels. Unfortunately, almonds have allergy potential in individuals (Sethi et al., 2016; Silva et al., 2020). Almond milk is rich in vitamin E (6.33%) in the form of α-tocopherol and manganese. Vitamin E is a powerful antioxidant with a protective role against free radical reactions (Karimidastjerd and Gulsunoglu Konuskan, 2021; Chalupa-Krebzdak et al., 2018).

The purpose of this study was to develop and evaluate two varieties of plant-based milk (soybean and almond). The evaluation consists in determining the rheological, physical, chemical, nutritional and sensorial proprieties. The plant-based milk, taken into the study, was both prepared by us and purchased from supermarkets.

In the present study were evaluated the physicochemical characteristics of plant milk beverages: vitamin C content, pH, acidity, salinity, total content of soluble solids - TSS, sensorial and rheological characteristics; and we investigated total mineral content (ash), moisture (water content) and total dry substances content - TDC, macronutrients content (fat, carbohydrates and protein content) on soybean and almond kernels used for homemade plat milk and for plant milk samples.

MATERIALS AND METHODS

Reagents and chemicals

All reagents employed in this study were of analytical grade and were purchased from Merck (Germany), Sigma-Aldrich (Germany) and Fluka.

Materials and preparation of samples

In this study, we prepared plant milk samples at room temperature from almonds and soybeans. Fresh spring water was used for preparing the plant milk. Soymilk was also prepared by boiling. The preparation method at room temperature (220C) (without heating or boiling) is also called the raw vegan preparation method. The products obtained through this process are called raw vegan products.

In the present study, soybeans and almond kernels purchased from Romanian supermarkets and plant-based milk (which was prepared at home or purchased from the supermarket) were evaluated. The plant-based milk samples purchased from local supermarkets are described in Table 1. In the selection of products, brands with significant domestic sales but with different ingredients were taken into account.

Table 1. Ingredient lists of the commercial plant beverages studied

Products	Ingredients lists
A Almond milk	water, almonds (2.3 %), calcium (calcium carbonat), sea salt, stabilizer agent (agar gum, gellan gum), emulsifier (lecithin), natural flavour; 100% Mediterranean almonds, no sugar, no sweeteners, low in fat, source of Ca and vitamins: B2, B12, D2, and E
B Soymilk	water, decorticated soy beans (8%), sugar, acidity corrector (potassium phosphates), calcium (calcium carbonate), stabilizer agent (gellan gum), source of Ca and vitamins:B12, D2,free for dairy and gluten

Preparation of homemade vegetable milk was achieved using a vegetable milk Biovita-10 device, which contains an incorporated blender. This device can grind and boil, not needing another device to grind, shred and blend.

For the preparation of raw plant milk, the ratio between the plant quantity and the spring water quantity was 1: 3 for almond milk and 1: 5 for soymilk. It was used bottled spring water bought from the supermarket, from local distributors. Distilled water was not used because it was desired to improve the mineral intake of the vegetable milk obtained.

Before introducing them in the device, the soybeans/or almond kernels had been soaked in water for twenty hours. Subsequently, the soaking liquid was drained and then the plants (the soybeans or almonds) and water were introduced into the device, during the process, the soybeans or almond kernels were ground very finely.

Finally, the resulting mixture (of soy/or almond and water), was filtrated through a very fine sieve (the diameter of the sieve being smaller than 0.5 mm), thus obtaining both the vegetable milk and the mass of solid vegetable substance (MSS) separated through draining. The experimental analysis has been conducted on both the raw material employed for the milk production and on the resulting products (the remaining solid mass (MSS) and the plant milk).

Four plant-based milk samples marked A, B, AM and SM were evaluated and analysed. A (almond milk) and B (soymilk) are two kinds of plant milk purchased from supermarkets. The analysed samples from homemade vegetable milk were AM, SM and BSM. The BSM sample is a soymilk sample obtained by boiling. The AM (almond milk) and SM (soymilk) are raw plant milk samples obtained by us.

Based on the analysed samples, the assessment of the following aspects has been made: the dry matter, content humidity, ashes, vitamin C content, pH, the Brix degree, salinity, and rheological behaviour.

Physical and chemical analyses

Weight determination. Soybean grains and almond kernels weight has been measured by using a digital balance with a sensitivity of 0.001 g.

The determination of water content and total dry weight. The moisture and total dry weight of samples were was made by using a Memmert drying oven, by drying at 105 ± 2°C until they reached constant weight (in 4 hours). The water content actually represents the weight loss achieved by heating at the temperature indicated by the analysis method until reaching the constant mass.

The ash content (total mineral content) was evaluated by incineration at 500 ± 15°C.

The term “ashes” designates the residue obtained from the alimentary products after the total elimination of the organic substances, by calcination and evaporation of water.

The determination of the total soluble solids TSS (the Brix degree) and of salinity in the milk samples has been achieved by employing the KRÜSS (Germany) optometric equipment.

The determination of pH has been obtained with the help of a pH-meter (Tester pH ExStick™ PH-100, Extech Instruments a FLIR Company) calibrated with pH 4 and 7 buffers.

The vitamin C content determination for the plant milk samples

The chemical methods of dosage for the ascorbic acid are based on its reducing property. The ascorbic acid is transformed by oxidation in dehydroascorbic acid.

The redox indicator 2,6-dichloroindophenol is a weak oxidizing agent with a mild oxidizing

action on the ascorbic acid (Dragan et al., 2008, Dinesh et al., 2015, Nielsen, 2017).
The method is based on the titration of the ascorbic acid in the vegetable extracts, with the redox indicator 2,6-dichloroindophenol, until it displays a pink colour which is persistent for 5 seconds (Nielsen, 2017).

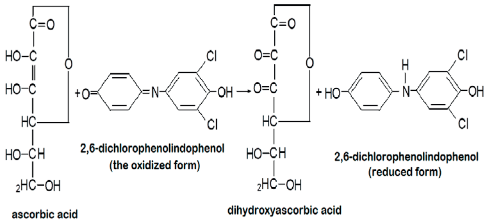

Figure 1. The reaction between ascorbic acid and 2,6-dichlorophenolindophenol

In the determination of vitamin C from samples, we used the method described by Dragan et al (2008) and Nielsen's readapted method (Nielsen, 2017).

Macronutrients composition

Both plants (soybeans and almond kernels) and plant milk samples were analysed by various methods to determine their nutritional and chemical composition (lipids, proteins, ash and carbohydrates). The crude protein content (Nx6.25) found in the samples was estimated by the macro-Kjeldahl method. The crude fats were determined by extraction with petroleum ether from a known weight of dried and grinded grains, using a Soxhlet extractor. For plant milk, we applied the same evaluation methods as for milk. We used the MilkoScan S54B device. The amount of carbohydrates was calculated by differences, according to the following equation:

$$Carbohidrates\ (\%) = 100 - [\text{Proteins}\ (\%) + \text{Lipids}\ (\%) + \text{Moisture}\ (\%) + Ash\ (\%)]$$

The energy values of samples formulas was calculated according to the following equation:

$$Total\ Energy\ (kcal/100g) = 4 \times [\text{Proteins}\ (\%) + \text{Carbohydrates}\ (\%)] + 9\times [\text{Lipids}\ (\%)]$$

Sensory evaluation

For sensory evaluation were selected thirty panellists (15 females, and 15 males, aged between 19 and 22 years) to evaluate the aroma, colour, taste, smell, consistency and appearance of samples. This group was recruited from students of the Faculty of Food Science (University of Life Science "King Mihai I" from Timisoara) based on their health condition and consumption frequency of plant protein-based products. The samples (40 mL) were served cold (15 ± 2°C) in 50 mL plastic cups codified with three-digit random numbers (each sample being three times given for tasting, without the panelists' awareness regarding this aspect). Mineral water at room temperature and saltwater biscuits were served to allow the assessors to cleanse their palates between samples. Each consumer evaluated the four samples (SM, AM, A and B) in a single session. The sensorial properties were evaluated by a hedonic scale test with a 5-point (1 = dislike extremely, 3 = neither like nor dislike, 5 = like extremely) at 25°C.

Statistical analysis

All determinations were performed in triplicate, calculating their arithmetic mean of three separate determinations. The data were statistically analyzed using the program Microsoft Excel.

RESULTS AND DISCUSSIONS

Rheological analyses

Flowing is a continuous deformation of fluid, which takes place when the resultant of forces acting on the fluid is not zero.
Pascal's fluid is not viscous, thus being an ideal fluid which cannot be encountered among real fluids.
From a historical point of view, the classic theory of fluid dynamics has developed based on the theoretical studies conducted by Pascal, Bernoulli and Euler on a fluid that lacks viscosity - the ideal fluid or Pascal's fluid.
Real fluids are those that resist deformation and flowing, due to the friction forces between the layers. The intensity of these forces is expressed in the dynamic viscosity of fluids, thus leading to the conclusion that real fluids have viscosity.

In many fluids, viscosity depends only on the fluid's state parameters and not on the parameters related to the forces acting on the fluid (the frictional force and the frictional speed). These fluids are named Newtonian fluids (Mateescu, 2008, Yao et al., 2022).
The fluids that show a uniform flow behaviour index - as is the case of Newtonian fluids - but also show flow tension ($\tau o > 0$) are called plastic fluids or Bingham plastic. The behaviour of such a material is similar to the behaviour of an elastic solid when the tension is below the value of flow tension/effort τo.
From a rheological point of view, fluids can be studied if they are subject to a continuous friction at a constant speed. Ideally, this friction can be understood by the image of 2 parallel plates, at a certain distance from each other, having a real fluid within the space between the plates. If an external force is applied on the superior plate, it will move in the action direction of the force with a constant speed which depends on the value of the force (Mateescu, 2008; Depypere et al., 2009; Yao et al., 2022). The inferior plate is fixed, not mobile. The speed of the superior plate can be defined as an infinitesimal variation of the position within an extremely short time frame.The force with a parallel action to the superior plate will induce a friction force on the superior plate, which can be considered a layer of fluid of an infinitesimal thickness. Due to the adhesion forces between the fluid and the solid, the layer of fluid adjacent to the superior plate will move with the plate, at a speed equal to the plate's speed. Due to the cohesive molecular forces, this particular layer will put into motion the inferior neighbouring layer, however at a slower speed, and so forth, so that the motion is transmitted gradually to the entire mass of the fluid located between the two plates.
Since there is no gliding on the solid margin, the layer of fluid adjacent to the inferior plate has a zero speed. The rheological behaviour of alimentary fluids depends on their composition and on the temperature. (Mateescu, 2008, Yao et al., 2022).
Their flow behaviour is also influenced by the shear speed (velocity), the shear duration and the pre-shearing time. Recording of the fluids rheograms is a common way of obtaining a rheological characterisation of an alimentary fluid, as complete as possible. Rheograms express the dependence of the shear stress on the shear speed (Mateescu, 2008; Depypere et al., 2009; Yao et al., 2022).
Plant bazed beverages has been characterized from a rheological point of view at temperatures ranging between 5-40°C, the interval for temperature rise being of 5°C.
Experimental rheograms for homemade soymilk (obtained at room temperature) shown in Figure 2 as linear dependences $\sigma = f(\gamma)$, (σ-shear stress, γ-shear speed). Row homemade soymilk behaves as a Newtonian fluid as well as soymilk prepared by boiling, which was described in a previous work (Rotariu et al., 2023).

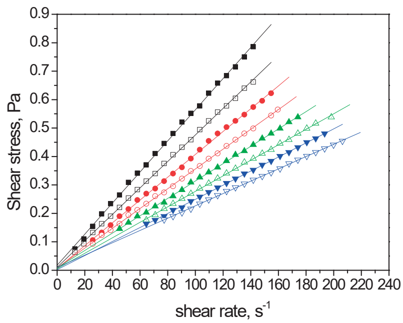

Figure 2. Rheograms for homemade raw soymilk – obtained at room temperature (■ – 5°C; □ – 10°C; ● – 15°C; ○ – 20°C; ▲ - 25°C; Δ – 30°C; ▼ – 35°C ▽ – 40°C; continous lines – calculated rheograms)

The characterization of boiled soybean milk and of purchased soybean milk was presented in a previous paper (Rotariu et al., 2023).
Table 2 indicates the viscosity values for all the eight evaluated temperatures. It can be noticed that this rheological characteristic is influenced by temperature, thus there is a decrease of viscosity levels as the temperature increases.

Table 2. The influence of temperature on the soybean milk viscosity

Temperature °C	Raw soybean milk	
	Viscosity mPa s	SD
5	5.47	0.04
10	4.65	0.03
15	4.01	0.03
20	3.48	0.02
25	3.05	0.02
30	2.73	0.02
35	2.48	0.01
40	2.16	0.01

Note: SD - Standard deviation

The influence of temperature on viscosity, shown in Figure 3, displays a linear decrease in viscosity as temperature rises. Consequently, from a rheological point of view soymilk behaves as a Newtonian fluid.

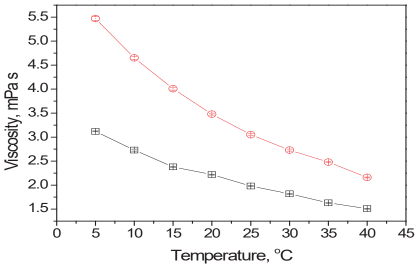

Figure 3. The influence of temperature on viscosity in soymilk (□ – homemade soymilk obtained by boiling); ○ – raw homemade soymilk)

Raw almond milk was evaluated rheologically at temperatures ranging between 5-35°C, the interval of temperature rise being of 5°C.

The experimental rheograms for raw almond milk are graphically expressed in Figure 4, in the form of variations σ = f (γ) nonlinear, (σ-shear stress, γ-shear velocity).

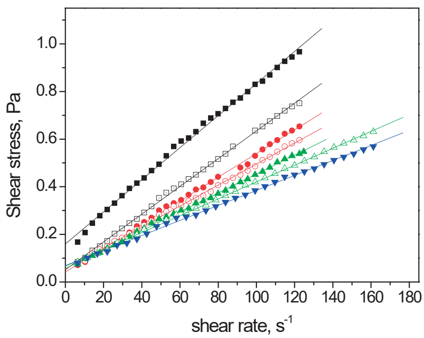

Figure 4. Raw almond milk rheograms (■ – 5°C; □ – 10°C; ● – 15°C; ○ – 20°C; ▲ - 25°C; Δ – 30°C; ▼ – 35°C; continuous lines – calculated rheograms)

The experimental rheograms graphically displayed in Figure 4 are in the form of variations σ = f (γ) linear, (σ - shear stress, γ - shear velocity). The non-linear variations suggest a non-Newtonian pattern of the fluid (raw almond milk), i.e. a Bingham character. (Mateescu, 2008; Yao et al., 2022). By non-linear regression, we determined the values of rheological properties for almond milk. The most appropriate model to apply in the case of this particular fluid is the Herschel-Bulkley model. Almond milk shows the behaviour of a Bingham fluid. Peanut milk had a similar character in the case of the studies by Yao et al. (2022).

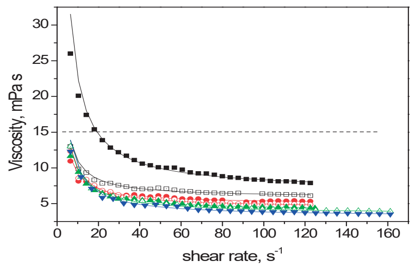

Figure 5. The influence of shear velocity on viscosity in raw almond milk (■ – 5°C; □ – 10°C; ● – 15°C; ○ – 20°C; ▲ - 25°C; Δ – 30°C; ▼ – 35°C; continuous lines – calculated viscosities; the dotted straight line at 15 mPa s represents the upper limit of the ordinate in this figure)

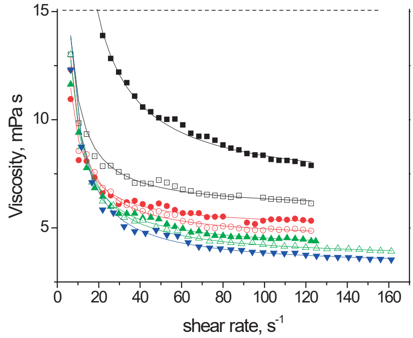

Figure 6. The influence of shear velocity on viscosity, for raw almond milk, in the range of viscosities below 15 mPa s (■ – 5°C; □ – 10°C; ● – 15°C; ○ – 20°C; ▲ - 25°C; Δ – 30°C; ▼ – 35°C; continuous lines – calculated viscosities)

Table 3 shows values for the flow effort and the plastic viscosity, at all seven studied temperatures. It can be noted that these rheological properties vary in relation to temperature; the flow effort reduces with the rise in temperature, and the plastic viscosity also decreases with the rise in temperature. This phenomenon is visible in Figure 7, which shows a pronounced decrease of viscosity when the shear velocity is higher.

Table 3. The rheological characteristics of raw almond milk, calculated for its behaviour as a Bingham fluid

Temperature, °C	Flow effort, mPa	SD	Plastic viscosity, mPa s	SD
5	159.79	5.15	6.74	0.07
10	51.70	2.61	5.83	0.04
15	41.69	3.04	4.98	0.04
20	54.64	2.36	4.41	0.03
25	56.60	1.99	3.97	0.03
30	66.25	1.70	3.54	0.02
35	69.30	2.50	3.15	0.03

Note: SD - Standard deviation

The influence of temperature on the values of rheological properties is described graphically in Figure 7 (for the flow effort) and Figure 8 (for the plastic viscosity).

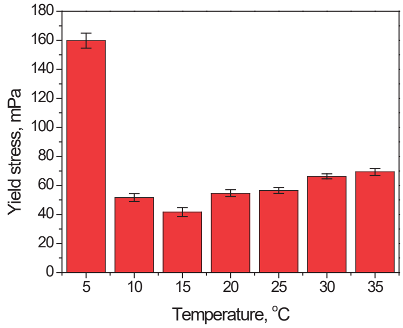

Figure 7. The influence of temperature on flow effort, in raw almond milk (the standard deviation is marked as ±Y bars)

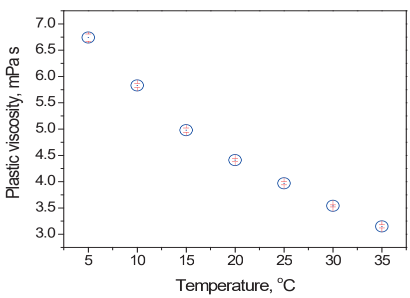

Figure 8. The influence of temperature on plastic viscosity, in raw almond milk (the standard deviation, in red, is marked as ±Y bars)

The experimental data indicate that the influence of temperature on the flow effort, in almond milk - Figure 7 - manifests as follows: the temperature rise determines the decline of the flow effort, up to 15°C temperature, and afterwards an increase of the flow effort takes place. On the contrary, the plastic viscosity of raw almond milk (Figure 8) shows a decrease, as the temperature rises.

Physicochemical and nutritional properties of soybean and almond kernels

The results of the physical, chemical and nutritional characterization of fruits (soybean and almond kernels) used for preparation plant milk are shown in Table 4.

Table 4. Physical and chemical characterization of the soybean and almond kernels

Parameters	Soybean	Almond kernels
Fruit weight, g	0.22	1.09
Moisture (g/100 g)	10.15	17.93
TDW (g/100 g)	88.98	82.07
Protein (g/100 g)	36,09	26.47
Lipids (g/100 g)	17.01	47.08
Carbohydrates (g/100 g)	31.64	5.61
Ash (g/100 g)	5.11	2.91
Energy (kcal/100 g)	423.96	552.04
TDW: Total dry weight, TSS: total soluble solids		

Nutritionally speaking, soybean is a protein-rich product. This fact may also be observed in the soybeans that we use for milk preparation. Amongst the macronutrients, the protein content of soybeans is the highest (36.09 g/100 g), followed by carbohydrates (31.64 g/100 g). In almond kernels, lipid content is the highest (47.08 g/100 g), followed by protein (26.47 g/100 g), and carbohydrates have the lowest content.

Physicochemical and nutritional properties of plant-based milk

The results of the basic nutritional and physico-chemical characterization plan-based milk beverages are shown in Table 5.

Table 5. A nutritional and physico-chemical characterization of the plant milk beverages

Parameters	A	AM	B	SM
pH	6.18	6.02	6.87	6.18
TSS (°Brix)	8.9	7.6	9.2	4.9
Salinity	8.5	6.4	4.3	3.9
Moisture (g/100 g)	95,57	93.21	91.9	92.3
TDW (g/100 g)	4.43	6.79	8.1	7.77
Ash (g/100 g)	0.4	0.63	0.43	0.37
Carbohydrates (g/100 g)	2.39	2.08	2.54	3.3
Protein (g/100 g)	0.45	2.3	3.33	2.9
Lipids (g/100 g)	1.19	1.78	1.8	1.2
Energy (kcal/100 g)	22.07	34.14	39.56	35.6

From the data displayed in Table 5 it can see that the value of total soluble solids content (TSS content - brix degree) was prominent in B sample (9.2) and the lower value (4.9) measured for SM sample (homemade soymilk). The brix values are higher for raw almond milk (7.6) as compared to soymilk. As regards the pH, one may notice that the values range within the 6.18-6.87 frame. The highest pH value belongs to B sample, while the lowest is recorded for the milk prepared by us. Regarding salinity, the highest value was also found in the almond milk purchased from supermarkets and the lowest value was found in homemade soymilk. Plant-based milk prepared at home has lower values than that purchased from stores. These low values can be explained and taking into account the fact that the preparation of milk was made only from fruit and water, no additives were used.

The data listed in Table 5 show that the lowest macronutrient content is found in soymilk purchased for supermarket (A sample). The differences between these A and AM samples can be explained by the fact that various soybeans quantities were used in proportion with the water added for the milk preparation. Likewise, for the improvement of milk sensory qualities other products are also introduced along with the "fruits" (soybeans and almond kernels), with specific macronutrient content.

The energetic value of the studied plant milk ranges between 22 and 40 (kcal/100 g). The lowest energetic value is found in almond milk purchased for supermarkets.

The energetic value of the studied homemade plant milk is around of 35 kcal/100 g (34.14 for AM and 35.6 for SM).

TSS values for soymilk are in the range from 8.1 to 10.10°Brix, reported by Terharg et al. (2013) and Micula et al. (2016; 2023), lower than those reported by Villegas, Carbonell and Costell (2011) for Spanish vanilla-flavored soy beverages (10.5 to 18.3°Brix). Callou et al. (2010) reported higher protein contents for soy beverages commercialized in the Brazilian market. Moore et al. (2023) reported, for soymilk and almond milk, close values of the content in macronutrients (Proteins - P, Lipids - L, carbohydrates - CH) and total mineral substances (ash). On the other hand, Milovanovic et al. (2023) reported lower values than the vegetable milk values studied by us.

This result confirms that the presence of aroma and flavour, darker colour, and different viscosity are important attributes in the acceptance of soymilk plain beverages. Villegas et al. (2011) have suggested that it is possible to increase the acceptability of vanilla-flavoured soy beverages by increasing their sweetness, viscosity, and intensity of vanilla flavour.

Sensory evaluation of plant based beverages

The results of sensorial assay are presented in Table 6 and Figure 9. Where, A and B sample are commercial products (described in Table 1).

Table 6. The sensorial and physico-chemical characterization of the soymilk sample

Parameters	SM	AM	A	B
Appearance	2.96	3	3.45	2.95
Colour	3.03	3.6	3.3	3.25
Consistance	2.59	3.65	4.6	4.06
Taste	2.05	3.59	4.7	2.95
Smell	2.46	3.65	3.75	3
Aroma	2.1	4	3.96	3.06

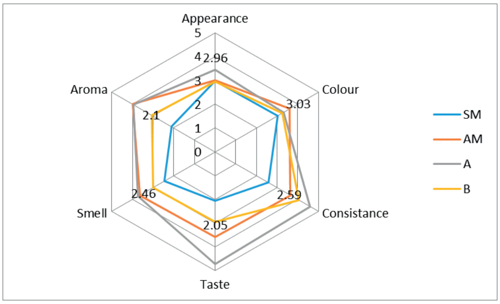

Figure 9. The sensorial characterization of the plant milk sample

One of the objectives of our research was to relate the physical and chemical characteristics of plant milk beverages to its sensory acceptance. From a sensorial point of view, the soymilk and almond milk samples from markets were well appreciated.

As expected, the least appreciated was the beverages prepared by us, since it does not contain any addition meant to improve its sensorial qualities, especially since it was prepared at room temperature, without other subsequent operations on the grains (such as roasting or germinating the grains, or others..

The least appreciated was the soymilk prepared by us,
The lowest score was registered on the taste level (2.05) and the highest score was recorded by the A (almond milk) sample, for the taste, (4.7).
The mostly appreciated sample from a sensorial point of view (B - soymilk and A - almond milk), displays the highest score for TSS (total soluble solids content.
Among the drinks prepared by us, the most appreciated was the almond milk, it received a score higher than 3, on the other hand, the soy milk was the least appreciated, the score obtained did not exceed 3, and for the taste, it was the lowest score of all assessments made.
On the aroma, the lowest level score was 2.1 for soymilk prepared by us and the highest score was 4 recorded by the AM sample (prepared by us) as well appreciated as the marketed one. The milk prepared by us can improve its sensorial qualities by adding some components (such as salt, inverted sugar, etc.), or in the preparation process to include other stages of 'grain' preparation, such as roasting etc. It was observed that the drinks prepared by Yao et al. (2022) were better appreciated, and the grains (that were used in the preparation of milk.) were roasted This fact can also be explained by these pretreatments performed on the grains.

CONCLUSIONS

This present study was designed to provide the scientific basis for developing plant-based milk by evaluating the physiochemical, rheological and sensory characteristics of two types of plant-based kinds of milk.
Soy beans and almond kernels are products with rich macronutrient content. Soybeans represent a significant source of protein, having beneficial properties for health. The moisture content in soybeans is relatively low. Almonds contain a large amount of soluble sugars, proteins, lipids, minerals, fibres and antioxidants.
Unlike milk of animal origin, plant milk contains neither cholesterol nor lactose, being an alternative food used by people who are lactose intolerant or have allergies to gluten and casein. It is also accepted by vegans, vegetarians and fasting people.
Homemade almond milk prepared by us behaves as a Bingham fluid. Non-linear dependences in the form of variations $\sigma = f(\gamma)$ nonlinear, (σ- shear stress, γ-shear velocity) suggest a non-Newtonian pattern of the fluid, a Bingham character. The most appropriate model to apply in the case of this particular fluid is the Herschel-Bulkley model. Soymilk - both the homemade one obtained at room temperature and one obtained by boiling - behaves as a Newtonian fluid. Linear dependences suggest a Newtonian character of the fluid (the soymilk).
The nutritional qualities of plant-based milk (almond and soy milk, respectively), are due to the high content of valuable nutrients for the human body, contributing to the energisation, vitaminization and mineralisation of the body.
The physical-chemical analyses of these raw-vegan preparations make it possible to know the intake within the recommended daily diet.
The presence of flavour, darker colour, and different viscosity degrees are important attributes in the acceptance of plant-based milk beverages.
The preparation recipe of homemade plant-based milk must be improved regarding all the physico-chemical and sensorial characteristics.
Therefore, future researchers or manufacturers could base the results obtained from this study and add food flavourings to make new kinds of plant-based milk alternatives more palatable to consumers.

REFERENCES

Aydar, E.F., Tutuncu S., Ozcelik B. (2020). Plant-based milk substitutes: Bioactive compounds, conventional and novel processes, bioavailability studies, and health effects, Journal of Functional Foods, 70, 103975.

Bonifacio da Silva J., Carrao-Panizzi M.C., Prudêncio S.H. (2009). Chemical and physical composition of grain-type and food-type soybean for food processing, Pesq. agropec. bras., Brasília, 44(7), 777-784.

Callou K.R.A , Sadigov S., Lajolo F.M., Genovese M.I. (2010). Isoflavones and antioxidant capacity of commercial soy-based beverages: effect of storage. Journal of Agricultural and Food Chemistry, 58(7), 4284-4291.Chalupa-Krebzdak, 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.
Depyperea F., Verbekena D., Torresb J.D., Dewettinck K. (2009). Rheological properties of dairy desserts prepared in an indirect UHT pilot plant, Journal of Food Engineering, 91, 140–145.
Dinesh B., Yadav B., Deepak Reddy R., Sai Padma A., Sukumaran M.K. (2015). Determination of Ascorbic Acid Content in Some Indian Spices Int.J.Curr.Microbiol.App.Sci, 4(8), 864-868.
Dragan S, Iosif G, Socaciu C (Eds.) (2008), Alimentatia functionala cu componente bioactive naturale in sindromul metabolic, Eurostampa, Timișoara.
FDA. CFR-Code of Federal Regulations Title 21; FDA: Silver Spring, MD, USA, 2018
Fructuoso, I.; Romão, B.; Han, H.; Raposo, A.; Ariza-Montes, A.; Araya-Castillo, L.; Zandonadi, R.P. (2021). An Overview on Nutritional Aspects of Plant-Based Beverages Used as Substitutes for Cow's Milk. Nutrients, 13, 2650.
Karimidastjerd, A., Gulsunoglu Konuskan Z. (2021). Health benefits of plant-based milks as alternatives to conventional milk, (Erdal H. Editor), Health & Science (1st Edi), 293 – 310.
Kibar H., Ozturk T. (2008). Physical and mechanical properties of soybean, Int. Agrophysics, 22, 239-244.Kundu P., Dhankhar J., Sharma A. (2018). Development of Non Dairy MilkAlternative Using Soymilk and Almond Milk. Current Research in Nutrition and Food Science, 6 (1), 203-210.
Li Y.R., Yun T.T., Liu S., Qi W.T., Zhao, L.Q., Liu,J.R., Li A.K., (2016). Analysis of water-soluble bioactive compounds in commonly consumed soymilk in China, Journal of Food Composition and Analysis, 46: 29–35. Liu K, Soybeans: chemistry, technology and utilization, New York: Chapman and Hall, 1997.
Mäkinen, O.E., Wanhalinna, V., Zannini, E., Arendt, E.K. (2016). Foods for Special Dietary Needs: Non-dairy Plant-based Milk Substitutes and Fermented Dairy-type Products. Crit. Rev. Food Sci. Nutr., 56, 339–349.
Mateesu C. (2008). Reologia alimentului, Editura Eurostampa, Timișoara, Romania.
Micula, L., Popescu, S., Micu, D., Manea, D., Mateeescu C. (2016). Physical and chemical characterization of soybean and soybean milk, pp.251-258, 16th International multidisciplinary scientific Geoconference, Micro and nano Technologies, Advances in Biotechnology Section, vol I, Albena, Bulgaria, ISBN 978-619-7105-68-1, ISSN 1314-2704, DOI: 10.5593/sgem2016B61;
Milovanovic V., Petrovic M., Kurcubic V., Petkovic M., Miletic N., Đurovic I. (2023). Comparison of cow's milk with plant-based milk alternatives: selected chemical and physical analysis, Conference: 1st INTERNATIONAL SYMPOSIUM ON BIOTECHNOLOGY XXVIII Savetovanje o biotehnologiji sa međunarodnim učešćem, At: Faculty of Agronomy Čačak, Serbia, Proceedings, 517-522.
Munekata, P.E.S.; Domínguez, R.; Budaraju, S.; Roselló-Soto, E.; Barba, F.J.; Mallikarjunan, K.; Roohinejad, S.; Lorenzo, J.M. (2020). Effect of innovative food processing technologies on the physicochemical and nutritional properties and quality of non-dairy plant-based beverages. Foods, 9, 288.
Nielsen, S.S. (2017). Vitamin C Determination by Indophenol Method. In: Food Analysis Laboratory Manual. Food Science Text Series. Springer, Cham. https://doi.org/10.1007/978-3-319-44127-6_15.
Omoni, A.O., Aluko, R.E. (2005). Soybean Foods and Their Benefits: Potential Mechanisms of Action, Nutr Rev., 63(8), 272-283.
Panghal A., Janghu S., Kumar V., Chhikara N. (2018). Potential non-dairy probiotic products – A healthy approach, Food Bioscience, 21, 80-89.
Rotariu L.S., Popescu G.S., Varsandan A., Amzoiu M.O. (2023). Proceeding of SGEM Conference, Viena, December 2023 – in press.
Sathe, S.K., Wolf, W.J., Roux K.H., Teuber, S.S., Venkatachalam M. (2002). Biochemical Characterization of Amandin, the Major Storage Protein in Almond (Prunus dulcis L.), J Agric Food Chem. 50 (15), 4333-4341.
Sethi S., Tyagi S.K., Anurag R.K. (2016). Plant-based milk alternatives an emerging segment of functional beverages: a review. Journal of Food Science and Technology, 53(9), 3408-3423.
Silva, A.R.A., Silva, M.M.N., Ribeiro, B.D. (2020). Health Issues and Technological Aspects of Plant-based Alternative Milk. Food Res. Int., 131, 108972.
Terhaag M.M., Almeida M.B., Benassi M.T. (2013). Soymilk plain beverages: correlation between acceptability and physical and chemical characteristics, Food Sci. Technol, Campinas, 33(2), 387-394.
Vanga, S.K.; Raghavan, V. (2018). How well do plant based alternatives fare nutritionally compared to cow's milk? J. Food Sci. Technol., 55, 10–20.
Villegas B., Carbonell I., Costell E. (2009). Acceptability of milk and soymilk vanilla beverages. Demographics consumption frequency and sensory aspects. Food Science and Technology International, 15(2), pp. 203-210.
Yao, Y., He, W., Cai, X., Bekhit, A.E.D.A. & Xu, B. (2022b). Sensory, physicochemical and rheological properties of plant-based milk alternatives made from soybean, peanut, adlay, adzuki bean, oat and buckwheat. International Journal of Food Science and Technology, 57, 4868–4878.