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Modelling and characterisation of plant-based yogurt produced with almond milk, and fortified with different concentrations of *Chlorella vulgaris*

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Abstract

In recent years, consumers' interest in plant-based dairy alternatives has surged, leading to a marketplace filled with various options. The present work, therefore, aimed to develop a novel functional yogurt-like product by combining almond milk with different concentrations of *Chlorella vulgaris* (0.25, 0.50, and 0.75%) to provide a quality alternative for individuals with lactose intolerance, milk allergies, or those following a vegan diet. The present work evaluated several quality parameters, including physicochemical, rheological, microbial, and sensorial characteristics. On the first day of storage, the energy values were highest in the A sample (99.59 kcal/100 mL) and lowest in the A75 sample (92.03 kcal/100 mL). The levels of calcium and magnesium were greater in the vegan yogurt fortified with *Chlorella vulgaris*. Additionally, increasing the amount of *Chlorella vulgaris* resulted in lower *L** values, and higher *a** and *b** values, than the control. The fortification of *Chlorella vulgaris* improved the firmness and cohesiveness of the vegan yogurt while reducing the consistency and viscosity index. The total phenolic content and antioxidant activity of the yogurts ranged from 4.98 to 43.22 mg GAE/100 g and 26.47 to 47.72%, respectively. Panellists rated the yogurt samples made with 0.25% *Chlorella vulgaris* and almond milk the highest.

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Introduction

The growing market share of alternative products worldwide reflects consumers' health motivations and lifestyle choices (Mäkinen *et al.*, 2016). Many individuals perceive vegan foods as healthier options (Brückner-Gühmann *et al.*, 2019). Both veganism and vegetarianism are increasingly recognised as lifestyles rather than merely dietary choices (Son and Bulut, 2016). Due to their sustainable production methods, many vegans opt for plant-based milk alternatives, viewing them as beneficial for personal health, environmental protection, and animal welfare (Raikos *et al.*, 2020). This dietary approach also addresses issues related to rising lactose intolerance, environmental concerns, and diets high in cholesterol (Haas *et al.*, 2019). Plant-based (PB) yogurt is primarily produced from various ingredients, including cereals and pseudocereals like oats, millet, and quinoa, as well as legumes such as soybeans, peas, and mung beans. Nuts such as almonds and walnuts, along with coconut, are also utilised (Klost *et al.*, 2020; Nie *et al.*, 2022; Zhao *et al.*, 2022; Yin *et al.*, 2024). For example, oat-based yogurts are prevalent in the Finnish market, while in the United States, they remain a relatively novel product. Although the presence of oat-based yogurts is on the rise in the US, there is still a significant gap in the number of available oat yogurt brands between the two countries (Gaan *et al.*, 2020; Greis *et al.*, 2023).

Almond milk is rich in antioxidants, which may help protect against chronic diseases such as cancers and heart diseases. Homemade almond milk is also known to be a good source of calcium (Haas *et al.*, 2019; Sunidhi *et al.*, 2021). Additionally, almond milk is the most preferred plant-based milk for yogurt production due to its high nutritional quality, prebiotic effects, and contributions to health (Sethi *et al.*, 2016; Jeske *et al.*, 2018; Stall and Adams, 2017; Chalupa-Krebzdak *et al.*, 2018). With its low lipid profile, almond milk features a balanced

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sodium/potassium and calcium/phosphorus ratio, making it stand out among vegan milk alternatives, such as hazelnut milk, as a suitable substitute for cow's milk (Luengo, 2009; Bernat *et al.*, 2015). The present work thus aimed to utilise almond milk, noted for its rich nutritional profile, and enhance its functionality by fortification with *Chlorella vulgaris* microalgae. Microalgae are used as functional food ingredients to produce superior, high-quality foods in terms of nutritional value (Kreitlow *et al.*, 1999). One of the most notable microalgae is *Chlorella vulgaris*, a species of green algae that contains astaxanthin, canthaxanthin, and small amounts of colorants, including β-carotene and lutein (Zielke *et al.*,1978; Beheshtipour *et al.*, 2012). *Chlorella vulgaris* contains eight essential amino acids, proteins, B vitamins, ascorbic acid, β-carotene, chlorophyll, *Chlorella* Growth Factor (CGF), and minerals such as potassium, sodium, magnesium, iron, and calcium (Rodriguez-Garcia and Guil-Guerrero, 2008). Moreover, *Chlorella* exhibits health-protective roles against various diseases, including stomach ulcers, wounds, constipation, anaemia, hypertension, and diabetes (Mello-Sampayo *et al.*, 2013).

Research indicates that *Chlorella vulgaris* has positive effects on yogurt production from cow's milk; however, no studies have explored its application with plant-based milk. Additionally, literature reviews reveal limited information on yogurt production using almond milk in comparison to cow's milk. Notably, there is currently no evidence of yogurt being produced exclusively from almond milk. Therefore, the present work aimed to evaluate the quality parameters of yogurt made from almond milk fortified with *Chlorella vulgaris*, thereby contributing to the existing body of knowledge.

Materials and methods

Materials

Chlorella vulgaris and almonds were purchased from a local market. The yogurt cultures (*Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*; Peyma-Hansen, Istanbul, Turkey) were obtained from Chr. Hansen.

Preparation of almond milk

Raw almonds were soaked in water at a ratio of 1:3 for 18 - 20 h in a beaker covered with cling film at 4°C. After the soaking was completed, the water was removed, and manual peeling was performed. Almonds were mixed with water at a ratio of 1:4 by weight, and ground for 2 min using an Ultra-Turrax disperser (Daihan Scientific, Co., Ltd.; Sethi *et al.*, 2016). After homogenisation, the mixture was filtered using a cloth. The obtained almond milk was pasteurised at 80 - 85°C for 15 min. Then, hot filling was transferred into sterile containers, and stored at 4°C for analysis. The almond milk production flow chart is given in Figure 1.

Analysis of almond

Almond samples were crushed for 5 min in a food processor (Arçelik K-1190 Robolio, 700W, Arçelik Inc., Istanbul, Turkey). The dry matter, protein, and ash contents were determined following the AOAC (1990), Cemeroğlu (2013), and Uylaşer and Başoğlu (2016) methods. The carbohydrate

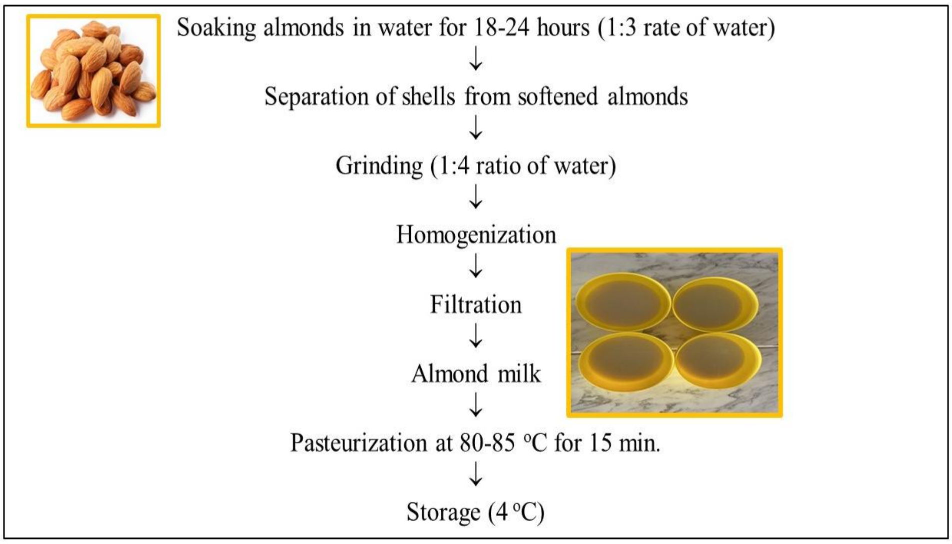

Figure 1. Flow chart of almond milk production.

content was determined by adding the ash, moisture, fat, and protein levels discovered during the analysis, and subtracting them from 100 (Gibson, 1990). In addition, the energy value was determined as a result of calculating protein and carbohydrate values by multiplying with a factor of 4, and fat values by multiplying with a factor of 9 (Gibson, 1990). The colour values were determined using a HunterLab instrument (Colorflex-EZ, HunterLab, Virginia, USA). Fat was extracted from ground almonds using the Soxhlet extraction method (AOAC, 1990). Antioxidant activity was determined by the DPPH method (1,1-diphenyl-1-picrylhydrazil) (Maleki *et al*., 2015). The total phenolic content of almond methanolic extracts was evaluated using the Folin-Ciocalteu spectrophotometric method devised by Singleton *et al*. (1999) and calculated by Koşar *et al*. (2002). The mineral content was determined according to Akbulut and Özcan (2009) using the Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES) (Perkin Elmer Optima 2100 DV, CT, USA).

Analysis of almond milk

The pH of almond milk was determined using a pH meter (Eutech PH150 Model). The colour was determined by recording the $L*$ (0 for black; 100 for white), $a*$ (+ for red; − for green), and $b*$ (+ for yellow; − for blue) values using a HunterLab instrument (Colorflex-EZ, HunterLab, Virginia, USA; Cueva and Aryana, 2008). Viscosity assessments were conducted using a Brookfield viscometer (Model DV-1; Brookfield Engineering Laboratories, Inc., MA, USA; Gassem and Frank, 1991). The protein content was determined through the micro Kjeldahl method, calculating total nitrogen and multiplying it by a factor of 6.38 (Cemeroğlu, 2013). Evaluations of dry matter, ash, fat, total acidity, total carbohydrate, and total energy in the vegan milk samples were performed in accordance with the procedures outlined by Gibson (1990), Bradley *et al.* (1992), AOAC (2000), TSE (2002), Cemeroğlu (2013), and Uylaşer and Başoğlu (2016). The extraction of vegan milk samples followed the method described by Özcan *et al.* (2019). Briefly, 10 g of sample was combined with 10 mL of 75% methanol solution at room temperature for 4 h, then centrifuged at 1,420 *g* for 10 min, and the supernatant was filtered through a filter paper. For the analysis of total phenolic compounds,100 µL of the supernatant was mixed with 7.5 mL of distilled water, 500 µL of Folin-Ciocalteu reagent, and 1 mL of Na_2CO_3 solution. The absorbance was recorded using a spectrophotometer (UV-1700, Shimadzu, Kyoto, Japan) at a wavelength of 760 nm. Results were expressed in milligrams of gallic acid equivalent (GAE) per gram of yogurt sample (Singleton *et al*., 1999; İlyasoğlu *et al*., 2015). The antioxidant activity of almond milk was evaluated using the DPPH free radical scavenging method, employing 80% methanol for the DPPH solution. For the analysis, 5 mL of 80% methanol was combined with 5 mL of almond milk. After mixing in a vortex for 1 min, the mixture was centrifuged at 4,000 rpm for 20 min. Subsequently, 0.1 mL of the clear supernatant was taken and mixed with 3.9 mL of DPPH solution. After 40 min in the dark, readings were taken at a wavelength of 517 nm (Blois, 1958). For mineral analysis, samples were incinerated in a muffle furnace at 550°C, cooled in a desiccator, and treated with 2 mL of HNO_3. The samples were then filtered through Whatman 42 filter paper, and diluted to a final volume of 100 mL with distilled water. Mineral content was measured using the ICP-OES (Perkin Elmer Optima 2100 DV, CT, USA; Turan *et al.*, 2017). A sensory evaluation of almond milk samples was conducted by a panel of 15 individuals from the Department of Nutrition and Dietetics at Erzincan Binali Yıldırım University. Panellists scored each sample on a 5-point scale for appearance, consistency, taste, colour, odour, and overall acceptability, where 1 indicated "very poor" (disliked), 2 indicated "poor" (slightly liked), 3 indicated "neutral" (neither liked nor disliked), 4 indicated "good" (liked), and 5 indicated "excellent" (strongly liked).

Preparation of almond-based yogurts

Vegan yogurt was produced by pasteurising almond milk at 85°C for 15 min according to Koca *et al*. (2002). Different concentrations of *Chlorella vulgaris* were then added to the pasteurised almond milk: 0 (control), 0.25, 0.50, and 0.75%, respectively. The yogurt samples were labelled as A (control almond milk), A25 (almond milk and 0.25% *Chlorella vulgaris*), A50 (almond milk and 0.50% *Chlorella vulgaris*), and A75 (almond milk and 0.75% *Chlorella vulgaris*). Vegan yogurt starters were added to 100 mL of almond milk cooled to 40 - 45°C as 1.5 g of yeast and preactivation was carried out for 30 min. Then, this mixture was cooled to

42°C, and incubated for 8 - 12 h. Incubation was terminated when the pH values of the yogurt reached the range of 4.20 - 4.71. The vegan yogurts were stored at 4°C until analysis. The *Chlorella vulgaris*-fortified almond milk vegan yogurt sample production flow chart is given in Figure 2.

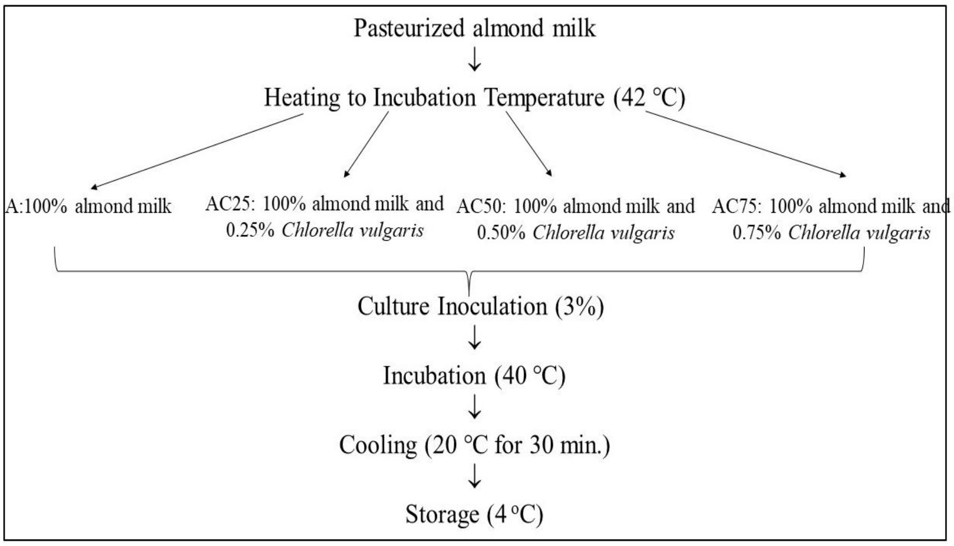

Figure 2. Flow chart of *Chlorella vulgaris*-fortified almond milk vegan yogurt production.

Physico-chemical analyses of almond-based yogurts

The pH of the samples was measured using a digital pH meter (Eutech PH150 Model). The analysis of almond milk yogurts followed the AOAC methods (AOAC, 2012) for determining dry matter, protein (Kjeldahl method), ash, and fat contents. To assess acidity, 10 mL of pure water at 40°C was added to 10 g of the sample, which was then titrated with 0.1 N NaOH using a 1 - 2% phenolphthalein indicator until a stable light pink colour was achieved, with results expressed in terms of lactic acid (Abou-Dobara *et al.*, 2016). A 25 g sample of vegan yogurt was filtered through filter paper, and after resting for 2 h at 4°C, the volume of separated serum was measured in mL, reported as mL per 25 g (Yılmaz-Ersan *et al.*, 2016). The total carbohydrate content and energy values were determined using the methods outlined by Gibson (1990). Colour evaluations of the samples, including *L** (brightness), *a** (red-green value), and *b** (yellow-blue value) were conducted using a HunterLab colour measurement instrument (Colorflex-EZ, HunterLab, Virginia, USA) (Kahyaoğlu *et al.*, 2005). Viscosity measurements were performed using a Brookfield viscometer (Model DV-1; Brookfield Engineering Laboratories, Inc., MA, USA; Gassem and Frank, 1991). Water-holding capacities were assessed by centrifuging a 10 g sample at 8,000 *g* for 15 min at 4°C (Bensmira and Jiang, 2012). The mineral contents, including Na, K, Ca, Mg, P, Cu, Fe, and Zn, was analysed using the ICP-OES (Perkin Elmer Optima2100 DV, CT, USA) (Skujins,1998).

Texture analysis, including firmness, consistency, cohesiveness, and viscosity index, was conducted using a TA-XT Plus texture analyser (Stable Micro Systems Ltd., UK), following the methodology outlined by Öztürk *et al.* (2018). A 30-mm disc-shaped probe was utilised to measure the distance during testing. In the back extrusion test, the probe was advanced into the sample contained in a 180 mL glass jar at a speed of 1 mm/s until it reached 75% of the sample height, after which it returned to the surface at a speed of 10 mm/s. For total phenolic content analysis, 10 g sample was combined with 10 mL of a 75% methanol solution, and allowed to stand at room temperature for 4 h before being centrifuged at 1,420 *g* for 10 min. The supernatant was subsequently filtered through a filter paper (Özcan *et al.*, 2019). Next, 100 µL of the resulting supernatant were mixed with 7.5 mL of distilled water, 500 µL of Folin-Ciocalteu reagent, and 1 mL of Na_2CO_3 solution. The absorbance of the samples was recorded at 760 nm using a spectrophotometer (UV-1800, Shimadzu, Kyoto, Japan; Singleton *et al.*, 1999; İlyasoğlu *et al.*, 2015).

For assessing the antioxidant activity, 3 mL of 60 mM 1-diphenyl-2-picrylhydrazyl (DPPH) reagent in 95% ethanol was mixed with 250 µL of yogurt water extract (Muniandy *et al.*, 2016). This mixture was allowed to incubate in the dark at room temperature for 1 h. The absorbance was then measured at 517 nm using a spectrophotometer, with a control consisting of 250 µL of ethanol instead of the extract. The calculation for radical scavenging activity was performed using Eq. 1:

$$\text{Radical scavenging activity (\%)} = (Abs_{control\ 517nm} - Abs_{sample\ 517nm} / Abs_{control\ 517\ nm}) \times 100 \quad \text{(Eq. 1)}$$

where, $Abs_{control}$ = absorbance of the control; and Abs_{sample} = absorbance of the sample.

Sensory evaluation

A panellist group of 15 people from the Department of Nutrition and Dietetics, Erzincan Binali Yıldırım University carried out the sensory properties of vegan yogurt. All vegan yogurt samples were evaluated on a 5-point scale based on their appearance, consistency, taste, colour, smell, and general acceptability.

Statistical analysis

The IBM SPSS statistical package (version 22) was used for the statistical analysis of the results. Results obtained were used to determine the difference within the variation at a 95% confidence level ($p < 0.05$).

Results and discussion

Proximate compositions of almond and almond milk

The nutrients, energy contents, and sensory properties of almonds used in production are presented in Table 1. The chemical composition values of almond samples were energy = 618.52 ± 3.39 kcal/100 mL; total fat = 51.44 ± 2.84%; protein = 18.73 ± 2.58%; carbohydrates = 20.16 ± 5.62%; ash = 3.80 ± 0.14%; humidity = 5.85 ± 0.35%; phenolic compounds = 0.07 ± 0.03 mg GAE/mL; DPPH radical scavenging activity = 60.91 ± 0.88%; *L** value = 70.52; *a** value = 4.58; and *b** value = 18.21. The mineral composition results of almonds were Na = 3.86 ± 0.41; K = 71 ± 2.65; Ca = 50.24 ± 0.62; Mg = 39.32 ± 1.63; P = 81.73 ± 1.88; Cu = 0.31 ± 0.01; Fe = 0.24 ± 0.00; and Zn = 0.62 ± 0.09 mg/100 g.

The proximate composition, nutritional composition, and antioxidative capacities of almond milk are presented in Table 1. Almond milk contained 83.54 ± 1.47% dry matter, 1.74 ± 0.29% ash, 5.00 ± 0.04% protein, 7.05 ± 0.21% fat, 30.26 ± 1.58% carbohydrate, 94.13 ± 4.50 kcal/100 mL total energy, a pH of 6.25 ± 0.17, 0.40 ± 0.00% acidity, 13.35 ± 0.04 cP viscosity, 0.19 ± 0.01 mg GAE/mL total phenolic content, and a DPPH radical scavenging activity of 46.12 ± 0.29%. The *L** value was 79.78 ± 0.19, the *a** value was 0.56 ± 0.02, and the *b** value was 6.72 ± 0.09. Additionally, in 100 mL of milk, the average mineral contents were 5.20 ± 0.20 Na, 62.65 ± 8.17 K, 16.17 ± 0.66 Ca, 44.10 ± 14.79 Mg, 64.33 ± 6.21 P, 0.09 ± 0.01 Cu, 2.40 ± 0.72 Fe, and 5.35 ± 3.04 mg/100 g Zn.

It was found that the P, K, Mg, and Ca contents of almond milk were high. The panellists appreciated the colour, appearance, and consistency of the almond milk, giving it an overall acceptability score of 3.60. The carbohydrate content of vegan almond milk (2.67 ± 1.58%) was lower than that of cow's milk (5.0%), human milk (6.8%), and melon seed milk (5.90%) (Onweluzo and Nwakalor, 2009; Omole and Ighodaro, 2012). Gallier *et al.* (2012) produced almond milk at a 1:3 dilution ratio, resulting in a dry matter ratio of 22.75 ± 0.22%. Hasan (2012) reported the ash value of almond milk to be 0.11 ± 0.01% at a dilution ratio of 4:100. Devnani *et al.* (2020) determined the protein value to be 3.5 ± 0.3%, and the fat value to be 9.5 ± 0.5% for almond milk prepared at a 1:4 ratio. According to Ceylan (2013), the total carbohydrate value of almond milk was found to be 1.15 ± 0.02 and 3.91 ± 0.01%, with energy values of 67 ± 0.03 and 103 ± 0.01 kcal/100 mL at dilution rates of 3 to 7 times. Bernat *et al.* (2014a) analysed carbohydrate values, reporting 1 - 8 g/100 mL for almond milk, 6.5 - 8 g/100 mL for hazelnut milk, 4.75 - 11.8 g/100 mL for oat milk, and 4.6 - 15.6 g/100 mL for rice milk. Although different results were reported due to varying dilution rates in the literature, it was noted that the energy values obtained in the present work were consistent with the energy values found in the literature. Devnani *et al.* (2020) found a pH value of 6.2 ± 0.2 in almond milk prepared at a 1:4 dilution ratio, while Kundu *et al.* (2018) assessed the acidity to be 0.390 ± 0.003%. Bernat *et al.* (2014b) determined the *L** value to be 87.83 ± 0.02 in their study, where almond milk was prepared with a dilution ratio of 8:100. Ceylan (2013) reported the antioxidant activity of almond milk at a range of 63.29 ± 0.01 to 72.32 ± 0.01%, also noting the total phenolic content to be 0.102 ± 0.001 and 0.553 ± 0.003 mg GAE/mL. Acceptability scores ranged from

6.10 ± 0.01 in three samples (prepared at a 6.4 dilution factor and 33°C) to 7.80 ± 0.02 in eight samples (prepared at a 3.6 dilution factor and 33°C), with an average score of 6.77 ± 0.02 (Ceylan and Özer, 2020). The research findings corroborated the conclusions of the present work, suggesting that the type of almond may also contribute to the variations observed in almond milk.

Table 1. Nutrients, energy contents, and sensory properties of almond and vegan almond milk assessed in the present work.

Composition	Almond	Almond vegan milk
Moisture (%)	94.13 ± 0.01	83.54 ± 1.47
Ash (%)	3.80 ± 0.14	1.74 ± 0.29
Fat (%)	51.44 ± 2.84	7.05 ± 0.21
Protein (%)	18.73 ± 2.58	5.00 ± 0.04
Total carbohydrate (%)	20.16 ± 5.62	2.67 ± 1.58
Total energy (kcal/100 mL)	618.52 ± 3.39	94.13 ± 4.50
pH	-	6.25 ± 0.17
Acidity (%)	-	0.40 ± 0.00
Viscosity (cP)	-	13.35 ± 0.04
Phenolic compounds (mg GAE/100 g)	0.07 ± 0.03	0.19 ± 0.01
DPPH (%)	60.91 ± 0.88	46.12 ± 0.29
Colour value		
*L**	70.52 ± 0.05	79.78 ± 0.19
*a**	4.58 ± 0.02	0.56 ± 0.02
*b**	18.21 ± 0.02	6.72 ± 0.09
Mineral content (mg/100 g)		
Na	3.86 ± 0.41	5.20 ± 0.20
K	71.63 ± 2.65	62.65 ± 8.17
Ca	50.24 ± 0.62	16.17 ± 0.66
Mg	39.32 ± 1.63	44.10 ± 14.79
P	81.73 ± 1.88	64.33 ± 6.21
Cu	0.31 ± 0.01	0.09 ± 0.01
Fe	0.24 ± 0.00	2.40 ± 0.72
Zn	0.62 ± 0.09	5.35 ± 3.04
Sensory analysis		
Appearance	-	4.35 ± 0.06
Consistency	-	4.08 ± 0.02
Flavour	-	4.29 ± 0.01
Colour	-	4.58 ± 0.02
Odour	-	3.98 ± 0.05
General acceptability	-	3.60 ± 0.05

Values are mean ± standard deviation. (-): not identified.

Vegan yogurt analyses

The physicochemical properties of yogurt made with almond vegan milk fortified with *Chlorella vulgaris* are presented in Table 2. The differences in average moisture, ash, protein, fat, carbohydrate contents, and energy values of the products were found to be statistically significant ($p < 0.05$).

As shown in Table 2, the highest dry matter content was 17.42% in the A75 sample on the last day of storage, while the lowest was 15.02% in group A on the first day of storage ($p < 0.05$). In all groups, the amount of dry matter increased on the last day of the storage period compared to the first day of storage. Furthermore, the increase in *Chlorella vulgaris* concentration also led to a statistically significant

Table 2. Physicochemical properties of yogurt samples with almond vegan milk fortified with *Chlorella vulgaris*.

Analysis	Sample	Storage time (day)			
		1	7	14	21
Moisture (%)	A	84.97 ± 0.03^{a,4}	84.83 ± 0.05^{a,1}	84.93 ± 0.04^{a,1}	86.21 ± 0.14^{a,1}
	AC25	84.35 ± 0.07^{a,3}	84.29 ± 0.02^{a,2}	84.14 ± 0.10^{ab,1}	84.05 ± 0.02^{b,12}
	AC50	83.98 ± 0.02^{a,2}	83.31 ± 0.05^{b,3}	83.13 ± 0.09^{bc,2}	83.05 ± 0.07^{c,12}
	AC75	83.01 ± 0.07^{a,1}	82.91 ± 0.04^{b,4}	82.80 ± 0.11^{bc,2}	82.58 ± 0.12^{c,2}
Ash (%)	A	0.64 ± 0.07^{c,1}	0.72 ± 0.01^{b,4}	0.86 ± 0.03^{a,3}	0.89 ± 0.02^{a,3}
	AC25	0.78 ± 0.02^{c,2}	0.81 ± 0.03^{bc,3}	0.86 ± 0.01^{ab,3}	0.92 ± 0.01^{a,3}
	AC50	0.98 ± 0.02^{c,3}	1.02 ± 0.03^{bc,2}	1.12 ± 0.07^{ab,2}	1.21 ± 0.07^{a,2}
	AC75	2.06 ± 0.04^{a,4}	2.04 ± 0.07^{a,1}	2.08 ± 0.02^{a,1}	2.11 ± 0.03^{a,1}
Protein (%)	A	5.78 ± 0.09^{a,1}	6.17 ± 0.07^{a,1}	6.12 ± 0.04^{a,4}	6.23 ± 0.03^{a,4}
	AC25	6.70 ± 0.03^{a,1}	6.74 ± 0.12^{a,1}	6.70 ± 0.01^{a,3}	6.87 ± 0.05^{a,3}
	AC50	6.98 ± 0.01^{d,1}	7.02 ± 0.02^{c,1}	7.09 ± 0.00^{b,2}	7.14 ± 0.01^{a,2}
	AC75	7.19 ± 0.01^{b,1}	7.21 ± 0.03^{b,1}	7.30 ± 0.01^{a,1}	7.32 ± 0.02^{a,1}
Fat (%)	A	6.45 ± 0.03^{b,1}	6.57 ± 0.05^{ab,2}	6.55 ± 0.04^{ab,3}	6.62 ± 0.02^{a,3}
	AC25	6.12 ± 0.01^{d,2}	6.60 ± 0.00^{c,12}	6.70 ± 0.07^{b,2}	6.79 ± 0.01^{a,2}
	AC50	6.46 ± 0.01^{b,1}	6.78 ± 0.02^{a,1}	6.80 ± 0.07^{a,1}	6.81 ± 0.01^{a,2}
	AC75	6.45 ± 0.04^{c,1}	6.74 ± 0.09^{bc,12}	6.86 ± 0.05^{ab,1}	6.94 ± 0.06^{a,1}
Total carbohydrate (%)	A	2.14 ± 0.86^{a,1}	1.69 ± 0.62^{a,1}	1.53 ± 0.07^{a,1}	1.44 ± 0.05^{a,2}
	AC25	2.05 ± 0.02^{a,1}	1.56 ± 0.12^{b,1}	1.47 ± 0.01^{b,1}	1.37 ± 0.02^{b,2}
	AC50	1.59 ± 0.04^{a,1}	1.86 ± 0.07^{a,1}	1.60 ± 0.03^{a,1}	1.78 ± 0.01^{a,1}
	AC75	1.26 ± 0.09^{a,1}	1.09 ± 0.09^{ab,1}	0.93 ± 0.16^{b,2}	1.04 ± 0.05^{ab,3}
Energy (kcal/100 mL)	A	99.59 ± 13.85^{a,1}	82.44 ± 11.49^{a,1}	89.57 ± 0.24^{a,2}	90.28 ± 0.67^{a,3}
	AC25	90.08 ± 0.09^{a,1}	92.60 ± 0.00^{c,1}	93.37 ± 0.45^{b,1}	94.27 ± 0.29^{a,2}
	AC50	92.44 ± 0.12^{b,1}	96.58 ± 0.02^{a,1}	95.69 ± 1.56^{a,1}	97.00 ± 0.12^{a,1}
	AC75	92.03 ± 0.13^{c,1}	93.88 ± 0.63^{b,1}	94.70 ± 0.28^{ab,1}	95.94 ± 0.85^{a,12}
pH	A	4.55 ± 0.08^{a,1}	4.54 ± 0.01^{a,1}	4.49 ± 0.00^{a,1}	4.47 ± 0.01^{a,1}
	AC25	4.53 ± 0.01^{a,1}	4.38 ± 0.01^{b,2}	4.21 ± 0.07^{c,2}	4.07 ± 0.01^{d,2}
	AC50	4.38 ± 0.02^{a,2}	4.26 ± 0.01^{b,2}	4.13 ± 0.01^{c,3}	4.03 ± 0.04^{d,2}
	AC75	4.24 ± 0.01^{a,3}	4.31 ± 0.08^{a,2}	4.06 ± 0.05^{a,3}	4.09 ± 0.03^{a,2}
Titratable acidity (%)	A	0.16 ± 0.07^{b,1}	0.19 ± 0.01^{a,3}	0.20 ± 0.07^{a,2}	0.21 ± 0.01^{a,2}
	AC25	0.18 ± 0.07^{b,12}	0.20 ± 0.01^{ab,23}	0.22 ± 0.02^{ab,12}	0.23 ± 0.01^{a,12}
	AC50	0.21 ± 0.01^{b,12}	0.23 ± 0.00^{ab,12}	0.24 ± 0.01^{ab,12}	0.25 ± 0.02^{a,12}
	AC75	0.22 ± 0.00^{a,2}	0.24 ± 0.02^{a,1}	0.26 ± 0.01^{a,1}	0.28 ± 0.03^{a,1}
Syneresis (mL/25 g milk-based yogurt)	A	18.41 ± 0.58^{b,1}	19.62 ± 0.03^{a,1}	20.36 ± 0.01^{a,1}	19.81 ± 0.25^{a,1}
	AC25	16.02 ± 0.88^{ab,1}	17.72 ± 0.73^{a,1}	16.22 ± 0.31^{ab,2}	14.58 ± 0.12^{b,2}
	AC50	15.88 ± 0.19^{a,1}	14.44 ± 0.20^{b,2}	14.74 ± 0.76^{ab,3}	14.06 ± 0.15^{b,2}
	AC75	14.61 ± 3.57^{a,1}	14.08 ± 0.85^{a,2}	11.06 ± 0.13^{a,4}	10.60 ± 0.51^{a,3}
Viscosity (cP)	A	968 ± 25.67^{d,1}	1158 ± 12.02^{c,1}	1239 ± 17.01^{b,2}	1647 ± 26.52^{a,1}
	AC25	989 ± 8.40^{c,1}	1093 ± 60.81^{bc,1}	1415 ± 20.50^{ab,12}	1479 ± 15.27^{a,1}
	AC50	985 ± 49.32^{c,1}	1107 ± 66.46^{c,1}	1408 ± 82.02^{b,12}	1626 ± 62.93^{b,1}
	AC75	1017 ± 16.72^{c,1}	1169 ± 8.48^{c,1}	1603 ± 11.59^{b,1}	1914 ± 55.86^{a,1}
Water-holding capacity (WHC) (%)	A	20.28 ± 0.02^{d,4}	23.66 ± 0.26^{c,2}	24.97 ± 0.03^{b,1}	26.22 ± 0.10^{a,1}
	AC25	27.58 ± 0.04^{a,1}	25.50 ± 0.28^{b,1}	22.44 ± 0.05^{c,2}	25.28 ± 0.02^{b,2}
	AC50	24.45 ± 0.64^{b,2}	23.18 ± 0.02^{c,3}	21.07 ± 0.03^{d,3}	26.07 ± 0.04^{a,1}
	AC75	22.37 ± 0.04^{a,3}	20.80 ± 0.18^{c,4}	19.49 ± 0.02^{d,4}	21.58 ± 0.15^{b,3}

Different lowercase superscripts in similar row indicate significant differences among the samples based on storage times ($p < 0.05$). Different numbers in similar column indicate significant differences among the samples based *Chlorella vulgaris* levels ($p < 0.05$). A: control (100% almond milk); AC25: 0.25% *Chlorella vulgaris*-fortified almond-based yogurt; AC50: 0.50% *Chlorella vulgaris*-fortified almond-based yogurt; and AC75: 0.75% *Chlorella vulgaris*-fortified almond-based yogurt.

increase in the dry matter content of the samples ($p < 0.05$). Atik *et al.* (2021) reported an increase in the total dry matter of kefir produced with soy and almond milk by adding *Spirulina* powder. The results of the present work agreed with the findings of that research.

The ash value in the samples was lowest in the A sample (0.64%) and highest in the A75 sample (2.11%), with a significant difference between the samples at the $p < 0.05$ level. Both storage time and an increase in *Chlorella vulgaris* concentration were effective in enhancing the ash content of the samples ($p < 0.05$). It was reported that the ash content of two rice-based yogurts (NYC-A and NYC-B cultures) obtained with different culture mixtures ranged from 0.39 to 0.40% (Plengsaengsri *et al.*, 2021).

The protein content of the vegan samples was determined to range from 5.38 to 7.32% on the 1st day of storage, and from 7.19 to 7.32% on the 21st day of storage. This variability in protein content during storage was found to be statistically significant ($p < 0.05$). The increase in protein content was also influenced by the concentration of *Chlorella vulgaris*. Yilmaz-Ersan and Topcuoglu (2022) reported protein values in the dry matter of probiotic yogurt samples with almond milk in the range of 1.01 to 4.14%. The findings of the present work differed from those of the research mentioned earlier. This could have been due to the fact that the microalgae used in the present work is an excellent source of protein, and the protein levels might have increased due to the higher concentration.

A75 yogurt (6.94%) had the highest fat content, followed by A50 (6.86%), A25 (6.74%), and A (6.45%) yogurt, and the results were statistically significant ($p < 0.05$). Öztürkoğlu-Budak *et al.* (2016) used nuts such as walnuts, hazelnuts, almonds, and peanuts in functional yogurt, and reported the fat content of yogurts fortified with hazelnuts as 5.80%, and those fortified with almonds as 5.37%.

The total carbohydrate values of vegan yogurt are presented in Table 2, varying between 0.93 and 2.14%. The lowest total carbohydrate ratio was detected on the 14th day of storage in the A75 sample, while the highest value was observed on the 1st day of storage in the A sample. The fortification of the samples with *Chlorella vulgaris* contributed to maintaining a low carbohydrate content in the vegan yogurts. The effects of storage on carbohydrate values were found to be significant ($p < 0.05$). The energy values calculated based on the energy provided by the nutrients are detailed in Table 2, with energy values ranging from 82.44 to 99.59 kcal/100 mL.

The pH value of the samples decreased continuously throughout the storage period, with the highest average pH value recorded on the 1st day in the A25, A50, and A75 samples, particularly in the control group. This finding agreed with Barkallah *et al.* (2017), who indicated that yogurt fortified with *Spirulina* had lower pH values compared to the control during storage. The titration acidity values of the samples varied between 0.16 and 1.28% during storage. The A sample (100% almond milk vegan yogurt) exhibited the lowest acidity value during the storage period, while the A75 sample (*Chlorella vulgaris*-fortified almond milk yogurt) showed the highest average acidity value. Taking storage time into account, the lowest acidity value was recorded on the 1st day at 0.16%, while the highest average acidity value was observed on the 21st day at 1.28%. Atik *et al.* (2021) reported that the acidity values of soy milk and almond milk kefir samples fortified with *Spirulina platensis* on the 1st and 7th days of storage were higher than those of the control yogurt.

The serum separation values of the yogurt samples are presented in Table 2. Serum separation was lowest on the 21st day of storage in the A75 sample (10.60 mL/25 g), and highest on the 14th of storage in sample A (20.36 mL/25 g). It was determined that the effects of sample type, storage time, and the interaction between sample type and storage time on the serum separation values were statistically significant ($p < 0.05$). Öztürkoğlu-Budak *et al.* (2016) found that syneresis tended to decrease in yogurt containing nuts (walnuts, pistachios, hazelnuts, and almonds), particularly in samples with almonds compared to others. To prevent serum separation in vegan yogurts, it is essential to strengthen the gel structure so that the network within the yogurt gel can adequately retain the serum phase (Vareltzis *et al.*, 2016).

Viscosity is an important property of foods that impacts the texture of fluids (Yu *et al.*, 2007). During the storage period, the highest viscosity was observed in the A75 sample at 1914 cP on the 21st day of storage, while the lowest viscosity recorded in the A sample was 968 cP on the 1st day storage. The effects of *Chlorella vulgaris* and storage on the samples were statistically significant ($p < 0.05$). It was found that serum separation values increased as the storage time progressed further.

The water-holding capacity (WHC) values of the samples are presented in Table 2, where *Chlorella vulgaris* was used in combination with almond milk to enhance vegan yogurt. The lowest WHC value recorded across all samples during storage was on the 1st day of storage for the A sample (20.28%), while the highest WHC value for the A25 sample was measured on the 1st day of storage at 27.58%. Atik *et al.* (2021) reported WHC values for kefir samples made with almond milk and fortified with *Spirulina platensis*, ranging from 13.35 to 22.00%, and for samples made with soy milk, ranging from15.30 to 21.85%. This corroborated the findings of the present work.

The mineral compositions of yogurt samples made from almond vegan milk fortified with *Chlorella vulgaris* are presented in Table 3. In 100 mL of vegan yogurt, the A sample contained the highest sodium content (425.71 mg), while the A50 sample had the lowest (420.41 mg). For potassium, the A sample had the highest content (810.39 mg), while the A50 sample had the lowest (796.75 mg). The highest calcium content was found in the A75 sample (180.00 mg), while the lowest was in the A25 sample (95.46 mg). The A75 sample also had the highest magnesium content (234.05 mg), while the A sample had the lowest (210.38 mg). Regarding phosphorus, the A sample had the highest level (535.45 mg), with the lowest in the A25 sample (530.19 mg). For copper, the highest concentration was in the A25 sample (0.858 mg), and the lowest was in the A75 sample (0.656 mg). The highest iron content was reported in the A25 sample (4.01 mg), while the lowest was in the A75 sample (3.86 mg). Lastly, zinc concentrations were the highest in the A sample (2.24 mg), and the lowest in the A50 sample (2.01 mg). An increase in calcium and magnesium levels was observed due to the higher concentration of *Chlorella vulgaris*. Additionally, the levels of salt, copper, and zinc in yogurt made solely with almond milk were found to be higher than in the other samples. The high mineral content of the vegan yogurt samples can be attributed to the significant mineral content of the almonds and milk used in their production.

Texture analyses

The firmness, cohesiveness, consistency, and viscosity index of yogurt samples fortified with *Chlorella vulgaris* in almond vegan milk are presented in Table 4. Regarding the firmness values of the yogurts, the lowest average was recorded at 0.54 N in the A sample, while the highest average was 0.89 N in the A75 sample ($p < 0.05$). Throughout the storage period, the firmness values exhibited varying tendencies based on the amount of *Chlorella vulgaris* used. The A75 vegan yogurt, which contained a higher concentration of *Chlorella vulgaris*, had a firmer texture than the other vegan yogurts due to its increased protein and total solids content. This finding can be attributed to the fact that a high protein content enhances the cross-linking of the gel network, resulting in a denser gel structure. Yilmaz-Ersan and Topcuoglu (2022) reported firmness values for probiotic yogurt fortified with almond milk ranging from 11.21 to 377.85 during storage. They found the lowest average value of 11.52 in the sample made with 100% almond milk, while the highest value was in the control sample (100% reconstituted milk) at 336.49.

Consistency values showed significant differences ($p < 0.05$) among the vegan yogurts throughout the 21-day storage period. The A75 sample had the lowest consistency value at 0.34 N.s, while the highest consistency value of 0.64 N.s was recorded for the A sample. The A sample also had the lowest cohesiveness value at 12.10 N, while the highest cohesiveness value was found in the A75 sample at 15.46 N. It was noted that as the concentration of *Chlorella vulgaris* in the samples increased, the cohesiveness values decreased. Arslan (2018) reported similar findings, noting that peanut milk resulted in decreased cohesiveness in yogurt samples.

Higher viscosity index values indicate greater resistance to gradual deformation under shear stress, correlating with thickness. The present work observed significant differences in viscosity index based on yogurt type and storage duration ($p < 0.05$). Maximum viscosity index levels were observed on the 1st day of storage for the A and A25 samples, while minimum levels were recorded on the 14th day of storage for the A50 sample (7.67), and on the 21st day of storage for the A75 sample (6.73).

Colour analysis

The colour values of *Chlorella vulgaris*-fortified almond milk vegan yogurt samples are presented in Figure 3. The highest L^* (lightness) value was found in the A vegan yogurt (78.70), while

Table 3. Mineral composition of yogurt samples with almond vegan milk fortified with *Chlorella vulgaris*.

Sample	Vegan yogurt mineral (mg/100 mL)							
	Na	**K**	**Ca**	**Mg**	**P**	**Cu**	**Fe**	**Zn**
A	425.71 ± 0.80	810.39 ± 0.01	173.09 ± 0.60	210.38 ± 0.72	535.45 ± 0.07	0.828 ± 0.02	3.94 ± 0.03	2.24 ± 0.02
AC25	423.52 ± 0.24	800.41 ± 0.38	95.46 ± 1.13	231.81 ± 3.23	530.19 ± 0.04	0.858 ± 0.03	4.01 ± 0.00	2.11 ± 0.06
AC50	420.41 ± 0.65	796.75 ± 2.20	177.90 ± 0.29	230.30 ± 1.98	531.26 ± 0.25	0.729 ± 0.20	3.99 ± 0.01	2.01 ± 0.00
AC75	424.52 ± 0.72	805.50 ± 1.23	180.00 ± 0.23	234.05 ± 1.37	534.40 ± 6.10	0.656 ± 0.03	3.86 ± 0.01	2.02 ± 0.03

A: control (100% almond milk); AC25: 0.25% *Chlorella vulgaris*-fortified almond-based yogurt; AC50: 0.50% *Chlorella vulgaris*-fortified almond-based yogurt; and AC75: 0.75% *Chlorella vulgaris*-fortified almond-based yogurt.

Table 4. Firmness, cohesiveness, consistency, and index of viscosity index results of yogurt samples with almond vegan milk fortified with *Chlorella vulgaris*.

Texture parameter	Sample	Storage time (day)			
		1	7	14	21
Firmness (N)	A	0.54 ± 0.06^{a,2}	0.57 ± 0.07^{a,2}	0.61 ± 0.04^{a,3}	0.63 ± 0.5^{a,3}
	AC25	0.61 ± 0.08^{a,12}	0.59 ± 0.06^{a,2}	0.70 ± 0.02^{a,2}	0.74 ± 0.01^{a,2}
	AC50	0.70 ± 0.01^{b,12}	0.61 ± 0.02^{c,2}	0.77 ± 0.02^{a,2}	0.80 ± 0.01^{a,2}
	AC75	0.79 ± 0.01^{b,1}	0.78 ± 0.02^{b,1}	0.84 ± 0.01^{ab,1}	0.89 ± 0.03^{a,1}
Cohesiveness (N)	A	12.82 ± 0.03^{a,2}	12.25 ± 0.02^{c,4}	12.58 ± 0.02^{b,3}	12.10 ± 0.05^{d,3}
	AC25	13.02 ± 0.02^{c,2}	13.29 ± 0.15^{bc,3}	13.66 ± .012^{ab,2}	13.83 ± 0.26^{a,2}
	AC50	13.79 ± 0.01^{a,2}	14.15 ± 0.11^{a,2}	14.56 ± 0.60^{a,1}	14.67 ± 0.46^{a,12}
	AC75	14.28 ± 0.30^{b,1}	14.94 ± 0.20^{ab,1}	15.23 ± 0.09^{a,1}	15.46 ± 0.33^{a,1}
Consistency (N.s)	A	-0.64 ± 0.01^{a,3}	-0.59 ± 0.01^{ab,1}	-0.56 ± 0.01^{b,1}	0.58 ± 0.03^{ab,1}
	AC25	-0.60 ± 0.01^{a,2}	-0.56 ± 0.01^{b,1}	-0.52 ± 0.00^{c,12}	-0.50 ± 0.01^{c,12}
	AC50	-0.56 ± 0.01^{a,2}	-0.49 ± 0.01^{b,2}	-0.48 ± 0.02^{b,3}	-0.44 ± 0.01^{c,2}
	AC75	-0.50 ± 0.00^{a,1}	-0.43 ± 0.04^{ab,2}	-0.35 ± 0.02^{b,4}	-0.34 ± 0.05^{b,3}
Viscosity index (N.s)	A	-8.97 ± 0.03^{a,1}	-8.46 ± 0.08^{c,1}	-8.67 ± 0.06^{b,1}	-8.40 ± 0.04^{c,1}
	AC25	-8.53 ± 0.11^{a,2}	-8.18 ± 0.02^{b,2}	-8.00 ± 0.04^{b,2}	-7.97 ± 0.06^{bc,2}
	AC50	-8.11 ± 0.02^{a,2}	-7.86 ± 0.08^{b,3}	-7.67 ± 0.03^{c,3}	-7.77 ± 0.06^{bc,2}
	AC75	-7.98 ± 0.02^{a,3}	-7.77 ± 0.05^{a,4}	-7.36 ± 0.08^{b,4}	-6.73 ± 0.19^{c,3}

Different lowercase superscripts in similar row indicate significant differences among the samples based on storage times ($p < 0.05$). Different numbers in similar column indicate significant differences among the samples based *Chlorella vulgaris* levels ($p < 0.05$). A: control (100% almond milk); AC25: 0.25% *Chlorella vulgaris*-fortified almond-based yogurt; AC50: 0.50% *Chlorella vulgaris*-fortified almond-based yogurt; and AC75: 0.75% *Chlorella vulgaris*-fortified almond-based yogurt.

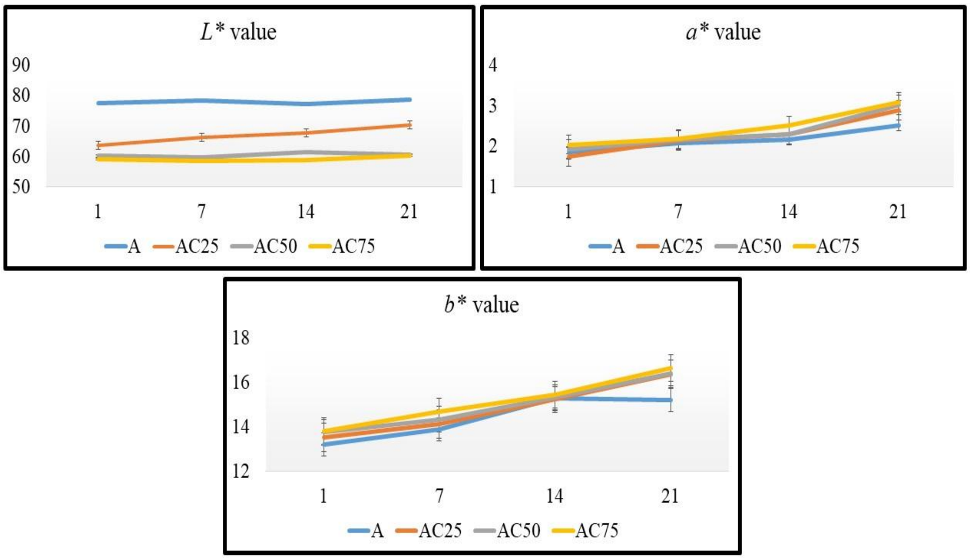

Figure 3. Colour values of samples. A: Control (100% almond milk); AC25: 0.25% *Chlorella vulgaris*-fortified almond milk vegan yogurt; AC50: 0.50% *Chlorella vulgaris*-fortified almond milk vegan yogurt; and AC75: 0.75% *Chlorella vulgaris*-fortified almond milk vegan yogurt.

the lowest value was found in the A75 sample (58.51). Atik *et al*. (2021) reported that the *L** value of the control sample was higher than that of *Spirulina platensis*-fortified kefir samples. This could have been due to the significant amount of chlorophyll present in *Spirulina* powder (Barkallah *et al.*, 2017). The findings of the present work which utilised *Chlorella vulgaris*—another microalga with a high chlorophyll content—agreed with those of the researchers. Among the yogurts, the highest *a** (redness) value was observed in the A75 vegan yogurt (3.08), followed by the A50, A25, and A samples, respectively. On the 1st day of storage, the A sample exhibited the lowest *b** value (13.19), whereas the A75 sample showed the highest *b** value (16.63). Yilmaz-Ersan and Topcuoglu (2022) found that the mean *L** values of their samples ranged from 61.44 to 81.54, *a** values from -0.41 to -3.30, and *b** values from 4.23 to7.75.

Total phenolic content and antioxidant capacity

The antioxidant activity and total phenolic content of the vegan samples are presented in Figure 4. The highest amount of total phenolic compounds was found in the AC75 yogurt (43.22 mg GAE/100 g), followed by AC50 (39.27 mg GAE/100 g), AC25 (30.77 mg GAE/100 g), and A (6.69 mg GAE/100 g), respectively. Almond milk is rich in phenolic compounds, including phenolic acids, flavonoids, and terpenoids (Yılmaz-Ersan *et al.*, 2016; Martins *et al.*, 2017). Both the ratios of almond milk and *Chlorella vulgaris* had a significant effect on the total phenolic content of the vegan yogurt ($p < 0.05$). Yilmaz-Ersan and Topcuoglu (2022) reported the total phenolic content of probiotic yogurt with almond milk that ranged from 50.69 to 22.17 mg GAE/L. The researchers noted a positive correlation between the increase in total phenolic content and the almond milk ratio. Atik *et al.* (2021) determined that the total phenolic content of *Spirulina platensis*-fortified soy and almond milk kefir samples ranged from 6.09 to 112.76 mg GAE/kg. According to the researchers, all *Spirulina platensis*-fortified soy milk kefir samples exhibited significantly higher phenolic content compared to almond kefir samples ($p < 0.05$). They attributed this result to the differing phenolic compounds likely produced by the distinct compositions of soy milk and almond milk.

Almond milk is an example of a food rich in bioactive substances with antioxidant properties, such as α-tocopherol and phenolic compounds (flavonoids and proanthocyanins) (Khalid *et al.*, 2017; Martins *et al.*, 2017). When examining the antioxidant activity values, the highest value was found in the A75 yogurt (45.78%), while the lowest value was found in the A yogurt (26.47%). A statistical difference was noted between the antioxidant activity values of almond milk yogurt fortified with *Chlorella vulgaris* and plain almond milk yogurt samples ($p < 0.05$) (Figure 4). Additionally, storage time significantly affected the antioxidant activity values of the samples. Arbağ (2022) reported the highest antioxidant activity values in hazelnut yogurt (62.13%), and the lowest in lentil yogurt (18.14%), among yogurts produced from vegetable milk sources including hazelnuts, almonds, oats, rice, chickpeas, and lentils.

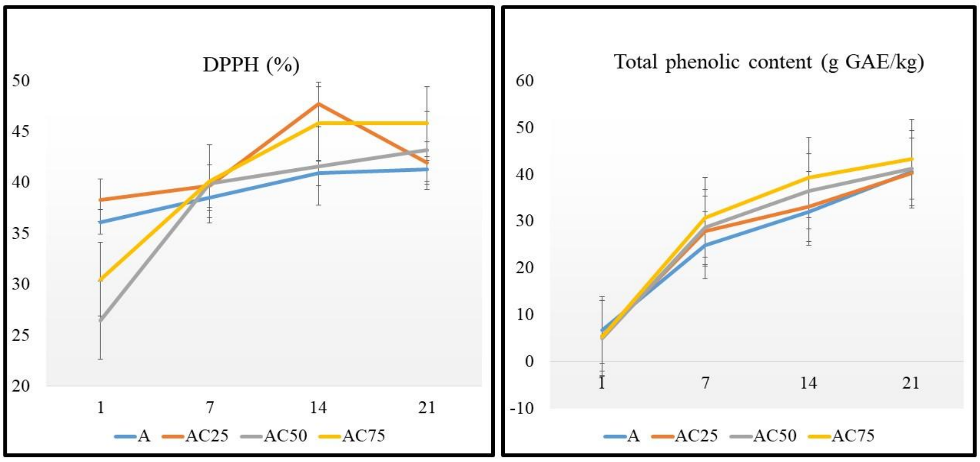

Figure 4. Antioxidant activity and total phenolic content of samples. A: Control (100% almond milk); AC25: 0.25% *Chlorella vulgaris*-fortified almond milk vegan yogurt; AC50: 0.50% *Chlorella vulgaris*-fortified almond milk vegan yogurt; and AC75: 0.75% *Chlorella vulgaris*-fortified almond milk vegan yogurt.

Sensory analysis

The mean scores for appearance, consistency, flavour, colour, odour, and general acceptability for all samples ranged as follows: 1.6 to 4.99 for appearance, 1.5 to 3.72 for consistency, 1.68 to 4.04 for flavour, 1.02 to 4.45 for colour, 1.05 to 3.06 for odour, and 0.9 to 4.35 for general acceptability (Figure 5). Regarding appearance, the panellists noted differences between the A sample and the *Chlorella vulgaris*-fortified samples stored for seven days ($p < 0.05$). In the panellists' evaluation, the A75 sample received the lowest appearance score (1.6), while the A sample received the highest score (4.99). The A75 sample also obtained the lowest consistency score of 1.5, while the A sample obtained the highest average consistency score of 3.72. Based on the analysis of variance for the vegan yogurt samples, the effects on the flavour values of the *Chlorella vulgaris*-fortified samples were statistically significant ($p < 0.05$). Among the samples produced, plain almond milk was the most appreciated in terms of odour. The panellists ranked the general acceptability scores from highest to lowest as follows: A, A25, A50, and A75. When comparing the samples based on storage time, the A75 sample received the lowest overall acceptability score (0.90) on the 21st day, while the A sample earned the highest score (4.35) on the 1st day of storage.

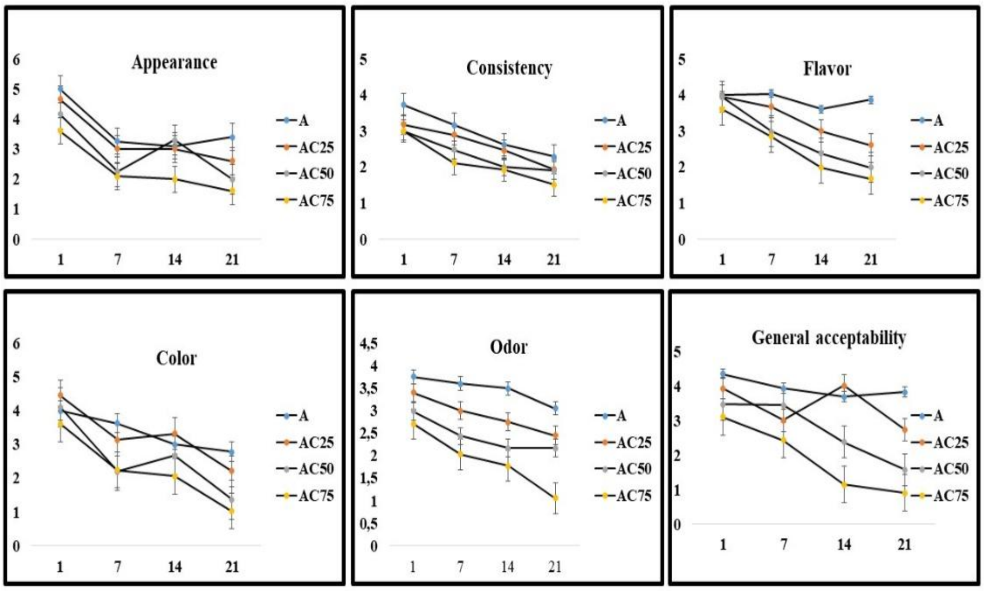

Figure 5. Hedonic test results for sensory evaluation of samples. A: Control (100% almond milk); AC25: 0.25% *Chlorella vulgaris*-fortified almond milk vegan yogurt; AC50: 0.50% *Chlorella vulgaris*-fortified almond milk vegan yogurt and AC75: 0.75% *Chlorella vulgaris*-fortified almond milk vegan yogurt.

Conclusion

The present work demonstrated that plant-based yogurt could serve as a viable and beneficial alternative to dairy yogurt, particularly for individuals with lactose intolerance or dairy allergies. The fortification of varying amounts of *Chlorella vulgaris* into almond milk-based yogurt resulted in notable enhancements in nutritional content, physicochemical properties, and sensory qualities. These results highlighted the potential of *Chlorella vulgaris* as a valuable additive for elevating the overall quality of plant-based yogurt products. The present work also underscored the significance of plant-based alternatives in addressing health issues associated with dairy consumption, offering a more inclusive choice for a diverse range of consumers.

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