



Vegan Cheese versus Regular Cheese: A Nutritional and Cytotoxic Assessment

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ABSTRACT

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Consumers are shifting to a plant-based lifestyle worldwide as more sustainable and healthier alternatives. However, despite the increasing popularity of plant-based vegan products, scientific evidence on their nutritional quality and health effects is still lacking. This study assessed the nutritional and cytotoxic characteristics of the vegan and regular cheese varieties sold in the retail markets in Istanbul, Türkiye in terms of total protein content, amino acid profile, vitamin B, calcium, and *in vitro* cytotoxicity using Kjeldahl, LC-MS/MS, HPLC, ICP-MS, and *in vitro* MTS assay, respectively. Our findings showed that the protein content in the regular cheese varieties was 20.7%, while it was 13.3% in vegan tofu only. The ratio between essential and non-essential amino acids in the regular and vegan tofu cheeses was 36.0/64.0 and 38.0/62.0, respectively. Vitamins B₆, B₉, and B₁₂ were detected in none of the varieties, and calcium levels were found to be 568.1 in the regular cheeses and 17.8 mg/100 g in the vegan cheeses. Besides, *in vitro*, MTS assay demonstrated that regular cheese Roquefort and vegan varieties significantly decreased the cell viability of the HTC-116 human colon cancer cell line. Overall, the current research highlights the need for a comprehensive evaluation of the vegan cheese types better to understand their nutritional, pre- and clinical toxicity, and bioavailability characteristics in a dose and time-dependent manner using advanced techniques and improving the nutritional quality of vegan products remains a challenge for the food industry.

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Introduction

A plant-based lifestyle is attracting much attention worldwide, and consumers are shifting to a plant-based diet (Clegg et al., 2021). One of the main focuses is to develop a broad range of alternative food and beverages as more sustainable and healthier alternatives than animal-based products. Despite attributing more attention to launching meat analogues, alternative plant-based dairy products other than “milk” or “cheese” or “yoğurt” are emerging in the food market (Boukid et al., 2021; Andreani et al., 2023). Plant-based dairy alternatives have negative environmental impacts compared to traditional dairy products on diverse indicators, including animal welfare (Cheng et al., 2022; Etter et al., 2024).

The regular cheese market size was valued at 172.6 billion dollars in 2023 and is estimated to reach 222.0 billion dollars by 2033 (Allied Market Research, 2024). Similarly, the vegan cheese market reached 2.7 billion dollars in 2023 globally and is projected to reach 6.9 billion dollars in 2032 (Imarc, 2024). Consumption is increasing rather than decreasing in both regular and vegan cheese consumption trends. However, more consumers are increasing their consumption of vegan cheese than regular cheese. For instance, in Spain, whilst 38% of consumers are increasing their consumption of vegan cheese, 15% are growing regular cheese consumption. Behind this trend, the protein claims are more likely to be a driver for

preferring regular cheese to vegan alternatives. Therefore, increasing the protein content of vegan cheese is becoming more evident (Fortune Business Insights, 2024; Innova Market Insights, 2024).

Regular cheese is rich in high-quality protein, A and B group vitamins, and other nutrients like calcium, phosphorous, and magnesium (Estévez et al., 2024). Given the emerging and increasing popularity of vegan cheese, the World Health Organization (WHO) is calling for more research on its nutritional quality and health effects in case of long-term consumption (Lin et al., 2023; Yu et al., 2023) since scientific evidence on the nutritional quality of the vegan cheese is still lacking (Fresán & Rippin, 2021). The main issue with the shift to vegan dairy products like vegan cheese is that they can not change their diet because plant-based products cannot provide all the essential nutrients needed for the body. For instance, in the United Kingdom, 25–70% of all the iodine consumed in the country is met by dairy and fishery products. However, the implication of vegan dairy products is the iodine deficiency (Alzahrani et al., 2023). Given the concerns about their nutritional and health impacts, it is critical to holistically evaluate the nutrient profile of vegan cheese varieties in relevance to health effects using a multidimensional approach (de Las Heras-Delgado et al., 2023). The nutritional quality of vegan cheeses was graded as D-E under the Nutri-Score system, compared to A-C for regular cheeses (Katidi et al., 2023). These products have generally been fortified to mimic the nutritional profile of regular dairy products, but the bioavailability and beneficial effects of the fortifying ingredients remain unclear (Geiker et al., 2020).

The current work had two objectives: (1) compare the label nutrient composition of vegan and regular cheeses, and (2) assess their nutritional and cytotoxic characteristics in terms of total protein content, amino acid profile, vitamins B₆, B₉ and B₁₂, calcium level, and *in vitro* cytotoxicity, respectively. This is the first study to perform a comparative assessment of the nutritional and cytotoxic impacts in Türkiye to help consumers make proper decisions about their vegan cheese preferences.

Material and Methods

Materials

The vegan (n=3) and regular cheese products (n=3) were sourced from the retail markets in Istanbul, Türkiye. Kjeldahl catalyst tablet (Merck 1.15348, Germany), sulfuric acid (H₂SO₄) (Merck 112080), boric acid (H₃BO₃) (Tekkim TK 40000073, Türkiye), hydrochloric acid (HCl) (Merck 109058), hydrolysis reagent (JASEM JSM-CL-508, Türkiye), sodium acetate (C₂H₃NaO₂) (Merck 106268), enzymes (taka-diastrase, clara-diastrase, papain, alpha-amylase, acid phosphatase, β-glucosidase, and pepsin (Sigma Aldrich, Germany), 0.45 μm syringe filter (Sigma Aldrich), phosphate-buffered saline (PBS) (HyClone, USA), methanol (CH₃OH) (Sigma Aldrich 1098229), sodium cyanide (Sigma Aldrich 380970), trifluoroacetic acid (Merck 302031), Dulbecco's Modified Eagle Medium (DMEM1x) (Gibco 11965092, USA), and trypsin-EDTA (Multicell 325-043-EL, Canada) were purchased. The cell line HCT-116 was obtained from the American Type Culture Collection (ATCC® CCL-247, USA).

Methods

Total Protein Analysis

Approximately 1-2 g of the sample was weighed on nitrogen-free filter paper and transferred to a Kjeldahl flask. A Kjeldahl catalyst tablet and 25 mL concentrated sulfuric acid (H₂SO₄) were added. The flask was placed in the InKJel digestion apparatus (Germany) and heated until the mixture turned green. After cooling, the flask was transferred to the Velp Scientifica UDK139 Kjeldahl distillation unit (Italy). During the distillation process, 3-4 drops of indicator and 100 mL of 3.5% boric acid solution (H₃BO₃) were added to the receiving Erlenmeyer flask. After distillation, the collected solution was titrated with 0.1 N hydrochloric acid (HCl) until it turned pink. The protein content (%) was calculated using the equations 1 and 2 (Tabak et al., 2021):

$$\text{Nitrogen (N) (\%)} = V_{\text{acid}} \times N_{\text{acid}} \times 1.4 / M \quad (1)$$

$$\text{Protein (\%)} = \text{N (\%)} \times 6.25 \quad (2)$$

Determination of Amino acid Composition

The Liquid Chromatography Mass Spectrometry (LC-MS/MS) method determined the samples' amino acid profile. Five hundred mg of the sample was placed into a screw-capped glass tube, and 4 mL of JASEM JSM-CL-508 hydrolysis reagent was added. The sample was hydrolyzed at 110 °C for 24 h. After hydrolysis, the hydrolysate was allowed to cool to room temperature and centrifuged at 4,000 rpm for 5 min. A 40 μL aliquot of the supernatant was pipetted and diluted to 1 mL with distilled water. From the diluted solution, 50 μL was transferred into a vial, mixed with 50 μL of an internal standard solution, and vortexed for 5 s. Subsequently, 700 μL of additional reagent was added, and the mixture was vortexed for another 5 s. Finally, the supernatant was transferred to an HPLC vial, and 3 μL was injected into the JASEM JSM-CL-575 amino acid column. The amino acid profile of the sample was analyzed using an Agilent 1290 Infinity coupled with an Agilent 6470 Triple Quadrupole System (USA). Amino acid concentrations were quantified with a limit of detection (LOD) of 0.001 mg/100 g and a limit of quantification (LOQ) ranging from 0.007 to 0.161 mg/100 g (Tabak et al., 2021).

Determination of Vitamins B₆, B₉ and B₁₂

Vitamin B₆

The sample was first homogenized, and 5-30 g of the homogenized sample was placed in 100 mL of conical flask. 60 mL of 0.1 N HCl solution was added to the sample and was autoclaved at 121°C for 30 min in MiproLab ML085 autoclave (Türkiye). The pH of the cooled sample was brought to 4.5 with the help of 2.5 M C₂H₃NaO₂ solution, and 100 mg taka-diastrase, 100 mg clara-diastrase, 50 mg papain, 20 mg alpha-amylase, 5 mg acid phosphatase and 10 mg β-glucosidase enzymes were added, respectively. After that, the solution was incubated at 45 °C for 3 h in the Lab Companion SI-300R shaking water bath (USA). The sample volume was then completed up to 100 mL with 0.1 N HCl solution. Finally, the solution was filtered using filter paper and a 0.45 μm syringe filter. The Agilent 1220 HPLC determined vitamin B₆ level with post-column derivatization under a fluorescence detector (Kall, 2003).

Vitamin B₉

The vitamin B₉ level was determined based on the peak area belonging to the extract in the buffer solution using a UV detector. A 1-2 g of the homogenized sample was weighed in a 100 mL conical flask, 25 mL of 0.1 M phosphate buffer and 20 mL of methanol (CH₃OH) were added and stirred for 30 min on a magnetic stirrer. Then, the mixture was transferred to a 50 mL test tube, supplemented with buffer solution, and centrifuged at 3,000 rpm. Vitamin B₉ levels were determined using the Agilent 1220 HPLC with post-column derivatization under a fluorescence detector (Hefni et al., 2010).

Vitamin B₁₂

A 1-10 g of the homogenized sample was weighed into a 250 mL conical flask, and 50 mL of 50 mM sodium acetate solution, 2 g of taka diastase, 1 g of pepsin, and 2 mL of 1% sodium cyanide solution were added. The mixture was stirred for 10 min and then incubated at 37°C for 30 minutes in a shaking water bath. The solution was heated at 100°C for 30 min, allowed to cool, and filtered through filter paper. The filtrate was passed through an immunoaffinity column at a 1 mL/min rate and washed with 10 mL of deionized water. Vitamin B₁₂ was collected using methanol. The extract was evaporated under nitrogen at 60-70°C, dissolved in trifluoroacetic acid, vortexed, and injected into the Agilent 1220 HPLC (Guggisberg et al., 2012).

Determination of Calcium Level

The samples were dissolved by microwave heating. The calcium (Ca) level was determined using the Agilent brand 7500cx model Inductively Coupled Plasma Mass Spectrometry (ICP-MS) (He et al., 2019).

In-vitro Cytotoxicity (MTS) Analysis

The effects of the vegan and regular cheeses on the cell viability of the HCT-116 cells were determined for 24 and 48 h by MTS [3-(4,5-dimethylthiazol-2-yl)-5-(3-carboxymethoxyphenyl)-2-(4-sulfophenyl)-2H-tetrazolium] assay. The cells were first incubated in Dulbecco's Modified Eagle Medium (DMEM1x) containing 10% FBS, 1% PSA, and 4.5 g/L D-glucose at 37 °C in a 5% CO₂-humidified atmosphere. After that, the cells were plated at a 5×10³ cells/well density into 96-well plates and subjected to 0.2 g samples dissolved in 1 mL growth media. 24 h after administration, the MTS reagent was added to the wells and incubated at 37 °C for 1 h in a 5% CO₂ humidified incubator. The absorbance was measured at 490 nm by the BioTek 800 TS ELISA microplate reader (USA). The Microsoft Excel program presented *in vitro* MTS readings as the median ± Sd (Abdik, 2022).

Data Analysis

The mean and standard deviations (Ss. ±) of the total protein (%), EAA non-EAA amino acids, vitamins, Ca levels, and cell viability data (CV) for the sample groups were calculated using the Microsoft Office Excel Program (USA).

Results and Discussion

Energy and Nutritional Labelling Data

A total of 6 cheese products were collected from the retail markets in Istanbul, Türkiye. Of them, 3 were vegan cheeses (white cheese 1, white cheese 2 and tofu), while 3 were regular (white cheese, halloumi and Roquefort). According to their labelled facts, the median energy content of the vegan varieties was 259±122 kcal/100 g, but that of the regular cheeses was 302±52 kcal/100 g. Amongst the vegan products, tofu cheese had protein (13.7 g/100 g). The halloumi cheese contained the highest protein amount, 25 g/100 g, within the regular ones. Regarding the carbohydrate content, the tofu had the lowest amount (1.1 g/100 g), whilst Roquefort had the highest amount (41.2 g/100 g).

Sugar was declared in the white cheese sample of the regular ones as 2.5 g/100 g only. The median fat levels in the vegan and regular cheeses were 21±12 kcal/100 g and 19±9 kcal/100 g, respectively. Saturated fat was present in the regular white cheese product only. However, none of the varieties had fibre. Salt was higher in the white cheese (2.7 g/100 g) than in the vegan ones (2 and 1.9 g/100 g) (Table 1).

Recent studies have investigated non-dairy vegan cheeses' energy and nutritional content worldwide. In the United States of America, the calories, fat, saturated fat, salt, and carbohydrates in the plant-based vegan cheese substitutes were reported as 80, 7, 4, 190, and 5 with no fibre, sugar and protein, respectively (Craig et al., 2022). In Sweden, the energy content of the vegan cheeses was also similar to or lower than regular cheese products (169 kcal/100 g), and the total fat, saturated fat, carbohydrate, total sugar, protein and salt levels were 15, 9.15, 5.95, 2.90, 1 and 0.11 g, respectively. Fibre content was significantly lower (0.60 g/100 g) (Moshtaghian et al., 2024). This study's labelled energy and nutrients data declared higher calorific value, fat and saturated content but lower protein, salt and fibre contents, except for the vegan tofu variety. The vegan analogues should ideally have a similar profile to the regular cheeses examined. Our nutritional labelling examination demonstrated similar or identical data for vegan and regular products.

Table 1. Labeled energy and nutritional data of vegan and regular cheeses

Energy/Nutrient (per 100 g portion)	Vegan cheese samples			Regular cheese samples		
	White Cheese 1	White Cheese 2	Tofu	White Cheese	Halloumi	Roquefort
Energy (kcal)	333	327	118	254	357	296
Protein (g)	-	-	13.7	16	25	10.2
Carbohydrate (g)	20	19	1.1	2.5	1.5	41.2
Sugar (g)	-	-	-	2.5	-	-
Fat (g)	28	27	6.5	20	27	9.8
Saturated Fat (g)	-	-	-	13	-	-
Fiber (g)	-	-	-	-	-	-
Salt (g)	2	1.9	-	2.7	-	-

Table 2. Total protein content in vegan and regular cheeses

Vegan cheeses	Protein (%)	Protein (%)	Regular cheeses
White Cheese 1	n.d.	24.3	Halloumi
White Cheese 2	n.d.	15.5	White Cheese
Vegan Tofu	13.3	22.3	Roquefort
Mean \pm SD.	n.d.	20.7 \pm 4.6	Mean \pm SD.

n.d.: not detected

Table 3. Essential (EAA) and non-essential amino acid (non-EAA) content (mg/100g) in the vegan and regular cheeses

Amino acid	Vegan cheeses			Regular cheeses		
	White Cheese 1	White Cheese 2	Tofu	White Cheese	Halloumi	Roquefort
EAA						
Histidine	n.d.	n.d.	380	580	740	910
Isoleucine	n.d.	n.d.	950	490	1480	750
Leucine	n.d.	n.d.	860	950	2410	1180
Lysine	n.d.	n.d.	600	640	930	1340
Methionine	n.d.	n.d.	210	390	250	410
Phenylalanine	n.d.	n.d.	710	430	1700	440
Threonine	n.d.	n.d.	320	390	910	600
Tryptophan	n.d.	n.d.	180	120	330	200
Valine	n.d.	n.d.	480	460	1270	770
Σ EAA	n.d.	n.d.	4690	4450	10020	6600
non-EAA						
Alanine	n.d.	n.d.	580	390	1020	760
Arginine	n.d.	n.d.	750	510	530	900
Aspartic Acid	n.d.	n.d.	1030	1200	1100	950
Aspartate	n.d.	n.d.	1030	1200	1100	950
Cystine	n.d.	n.d.	140	230	180	280
Cysteine	n.d.	n.d.	140	230	180	280
Glutamic Acid	n.d.	n.d.	1280	2400	1860	2920
Glycine	n.d.	n.d.	510	470	800	780
Hydroxyproline	n.d.	n.d.	600	430	480	600
Proline	n.d.	n.d.	470	640	930	860
Serine	n.d.	n.d.	920	930	3390	1040
Taurine	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Tyrosine	n.d.	n.d.	900	960	1890	1060
Σ non-EAA	n.d.	n.d.	8350	9590	13460	11380
Σ EAA + non-EAA	n.d.	n.d.	13040	14040	23480	17980

n.d.: not detected

Total Protein Content

The Kjeldahl method determined the total protein content of the vegan and regular cheeses. Among the vegan products, only protein was detected in vegan tofu (13.3%). Nevertheless, the regular cheeses' protein content ranged from 15.5 to 24.3% (20.7 \pm 4.6 mg/100 g) (Table 2).

The primary protein source in vegan cheeses is plant-based, including peas, soy, and lentils (Boukid et al., 2021). Nutritional information from vegan cheese substitutes available on the UK market was compared with the equivalent of regular cheese and revealed significant differences in protein compared to the regular equivalent (Clegg et al., 2021). Research in Spain showed that tofu-based vegan cheese had more protein than other vegan cheese varieties, which aligns with our findings. In Canada, the protein content of vegan cheese was increased to 18% using waxy starch, plant-protein isolate, and coconut oil (Dobson & Marangoni, 2023). Among the vegan cheeses, tofu is one of the most common conventional cheese varieties manufactured from soy milk (Diaz-Bustamante et al., 2023). The tofu-based cheese alternative reported approximately 16.6 g of protein/100 g serving (Craig et al., 2022). Filipczak-Fiutak et al. (2021) reported a protein content of 32.9% in smoked

cheeses made from goat, sheep, and cow milk in a study conducted in Poland. In our research, vegan tofu cheese's protein content was found to be 13.3 g/100 g, which is lower. In summary, our data on protein profile suggested that vegan cheeses may be considered practical alternatives to regular cheeses. However, they cannot fully meet nutritional requirements depending on the availability of plant-based protein ingredients.

Amino Acid Composition

The EAA and non-EAA values of the tofu cheese were 4690 (36%) mg/100 g and 8350 (63%) mg/100 g, respectively (13040 mg/100 g in total). On the other hand, the protein levels of regular cheeses changed from 14040 mg/100 g in white cheese to 23480 mg/100 g in halloumi and 17980 mg/100 g in Roquefort. The proportion of the EAA content was 31.6% in white cheese, 42.7% in halloumi, and 36.7% in Roquefort (Table 3).

In this study, taurine was not detected in the analyzed cheeses. Taurine is a conditional EAA (Rais et al., 2022). It influences the digestive and absorptive function of the small intestine through the conjugates' formation with bile acids (Hou et al., 2015). No significant amount of taurine

was found in any plant and regular cheeses, including Roquefort, Edam, Camembert, Feta and Gouda types (McCusker et al., 2014), which aligns with our data on taurine. In two studies, the most appreciable amount of amino acid in some regular cheeses was reported to be glutamine/glutamate (Filipczak-Fiutak et al., 2021; Dai et al., 2022), which exactly matches our results for white cheese (2400 mg/100 g), halloumi (1860 mg/100 g), and Roquefort (2920 mg/100 g). Interestingly, glutamine/glutamate was also significantly high (1280 mg/100 g) in the analyzed vegan tofu product, in line with Fathana et al. (2021). Overall, except for tofu cheese, the remaining two vegan cheese products lacked protein and amino acid availability, resulting in poor nutritional characteristics. On the other hand, the tofu had a balanced and similar amino acid profile compared to the examined regular cheese products.

Vitamins B₆, B₉ and B₁₂ Levels

The existence of three vitamins, B₆ (pyridoxine), B₉ (folic acid), and B₁₂ (cobalamin), in vegan and regular cheese products was measured by the HPLC technique. However, none of them were detected in the analyzed samples. Vitamins B₆, B₉, and B₁₂ are essential for cell metabolism and have strong protective antioxidant effects against reactive oxygen species (ROS) and some diseases like dementia and Alzheimer's (Yaman, 2019; Franco et al., 2022; Xu et al., 2022). Vitamin B₆ was found predominantly in legumes and grains ranging from 23.8 to 957.9 µg/100 g (Koscoglu, 2020). Santos et al. (2023) found that the B₆ level to be 0.01 mg/100 g in white cheese. In a study conducted in the United States, regular cheese samples had 94 µg/100 g of vitamin B₆ and 22.3 µg of vitamin B₁₂ (Shahani et al., 1962). Processing milk in cheese making is a critical factor in the level of vitamin B₁₂. For instance, approximately 70% of vitamin B₁₂ is lost during regular cheese manufacturing, and 3.72 ng/g remains undegraded (Xu et al., 2020). Overall, the unavailability of vitamins B₆, B₉ and B₁₂ in the examined vegan and regular cheese products may be attributed to the type and quality of the milk used in cheese production and the manufacturing technology.

Calcium Levels

The Ca level in the cheese types was determined using ICP-MS. The obtained data showed that the median Ca content of the vegan cheeses was 17.7±8.1 mg/100 g (23.9±5.0 mg/100 g in white cheese 1.86±1.8 mg/100 g in

white cheese 2, and 20.8±4.4 mg/100 g in tofu), while it was about 32x fold higher (568.1 ± 310 mg/100 g) in the regular cheese products (271.8±57.1 mg/100 in white cheese, 890.2±186.9 mg/100 g in halloumi, and 542.3±13.8 mg/100 g in Roquefort). In most regular cheeses, the Ca concentration has ranged between 73-1200 mg/100 g (Grasso et al., 2023). Another study reported the Ca level in plant-based vegan dairy products as 5-122 mg/100 g (Glover et al., 2024). Fortification of food and beverages with Ca is a common technique in the food industry to improve the nutritional profile of products. Nevertheless, this technique may produce undesirable techno-functional effects in vegan cheeses (Peng et al., 2021). Currently, vegan cheeses on the market contain starch and coconut oil; most of these products do not have added calcium. However, only a limited number have been fortified with Ca salts, including Ca phosphate, Ca citrate, or their blends (Kaharso et al., 2021; Craig et al., 2022). In summary, our data suggested that the analyzed vegan cheeses need fortification with Ca, but increasing the Ca level in the plant-based vegan cheeses depends on the techno-functionality limits of the products.

In vitro Cytotoxic Results

The time-dependent (24 h and 48-h) cytotoxic effects of vegan and regular cheese samples on the cell viability (CV) of the HCT-116 human colon cancer cell line were examined using MTS assay. 24 h after administration, the CV significantly decreased to 68±1.4% for vegan white cheese 1 and 68.9±0.4 for vegan tofu. However, no significant difference was observed among the other treatment groups. 48 h after administration, the CV significantly decreased in Roquefort (67.9±0.4%), vegan white cheese 1 (67.4±1.8%), vegan white cheese 2 (64.7±0.8%), and vegan tofu (68.3±0.7%), respectively (p<0.05) (Table 4, Figure 1).

Rafiq et al. (2019) evaluated the anti-proliferative activity of regular Cheddar cheese using the HCT-116 cell line and observed apoptosis induction in a dose-dependent manner. Similarly, Jovanović et al. (2023) demonstrated that certain cheese extracts exhibited cytotoxicity to HCT-116 cells (up to 30.9%). However, the data related to the cytotoxic effects of vegan cheeses remains unclear in the literature. Thus, our data suggested that vegan cheeses need further investigation on their anti-proliferative properties and induced apoptosis influence in the different cell lines of colon cancer.

Table 4. The cell viability (%) results of the vegan and regular cheeses on the HCT-116 cell line for 24 h and 48 h

Cheese types	Control		24 h		48 h	
	HCT-116 (%)	SD (±)	HCT-116 (%)	SD (±)	HCT-116 (%)	SD (±)
Vegan White Cheese 1	100	-	68	1.4	64.7	0.80
Vegan White Cheese 2	100	-	79.6	2.5	67.4	1.80
Vegan Tofu	100	-	68.9	0.4	68.3	0.70
Regular White Cheese	100	-	80.6	1.0	80.4	1.20
Halloumi	100	-	74.8	2.3	74.1	0.70
Animal-Based Roquefort	100	-	70	0.8	67.9	0.40

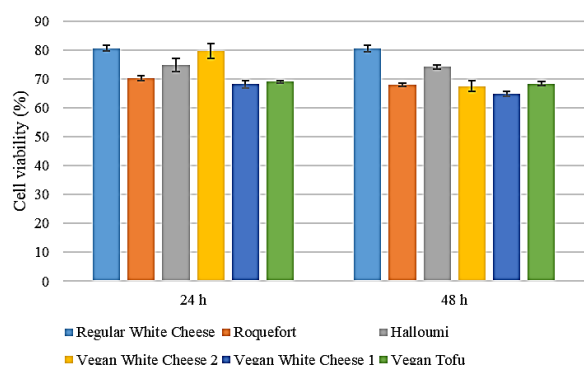


Figure 1. The cell viability (%) results of the vegan and regular cheeses on the HCT-116 cell line for 24 h and 48 h (One way ANOVA with Tukey Post Hoc test, * $p < 0.05$)

Conclusion

The current study assessed the nutritional and cytotoxic characteristics of the vegan and regular cheese varieties sold in the retail markets in Istanbul, Türkiye. Overall, the current research highlights the need for a comprehensive evaluation of the vegan cheese types better to understand their nutritional, pre- and clinical toxicity, and bioavailability characteristics in a dose and time-dependent manner using advanced techniques and improving the nutritional quality of vegan products remains a challenge for the food industry.

Declarations

Ethical Approval Certificate

The authors of this article declare that the materials and methods used in this study do not require ethics committee approval and/or special legal permission.

Author Contribution Statement

Sermin DURAK: Investigation, supervision, and writing the original draft, review and editing; Ayşenur DEMİRCİ: Investigation, data collection, review and editing; Aleyna ÇAVDAR: Data collection and investigation; Yasemin YILMAZER: Investigation, supervision, methodology, writing the original draft, review and editing; Serap ANDAÇ: writing the original draft, review and editing; İsmail Hakkı TEKİNER: Conceptualization, data collection, supervision, methodology, writing the original draft, review and editing.

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Conflict of Interest

The author reports no conflict of interest.

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