DOI: 10.29050/harranziraat.1652328
Harran Tarım ve Gıda Bilimleri Derg. 2025, 29(3): 549-561.

Research Article/Araştırma Makalesi

The role of tomato waste in enhancing nutritional, functional and sensory properties of fresh acid cheese

Domates atıklarının asitle pıhtılaştırılmış taze peynirin fonksiyonel, işlevsel ve duyusal özelliklerini geliştirmedeki rolü

Elif ÇAKIR[1*], Hatice BEKİROGLU[2], Muhammet Ali ÇAKIR[3], Osman SAĞDIÇ[4]

[1]Department of Food Engineering, Engineering Faculty, Istanbul Aydin University, PO Box 38, 34295, Küçükçekmece, Istanbul, Turkey
[2]Sırnak University, Food Engineering Department, Faculty of Agriculture, Şırnak University, Mehmet Emin Acar Campus, Şırnak 73000, Turkey
[3]Department of Food Engineering, Chemical and Metallurgical Faculty, Yıldız Technical University, Esenler, Istanbul 34210, Turkey
[4]Faculty of Health Sciences, Department of Nutrition and Dietetics, Kırklareli University, Kırklareli, Türkiye

[1]https://orcid.org/0000-0003-4343-3706; [2]https://orcid.org/0000-0003-3328-1550; [3]https://orcid.org/0000-0001-5066-1956; [4]https://orcid.org/0000-0002-2063-1462

To cite this article:
Cakir, E., Bekiroglu, H., Cakir, M.A. & Sagdic, O. (2025). The Role of Tomato Waste in Enhancing Nutritional, Functional and Sensory Properties of Fresh Acid Cheese. Harran Tarım ve Gıda Bilimleri Dergisi, 2025, 29(3): 549-561.

DOI: 10.29050/harranziraat.1652328

Address for Correspondence:
Elif CAKIR
e-mail:
cakir.elif2014@gmail.com

Received Date:
05.03.2025
Accepted Date:
28.08.2025

ABSTRACT

This study aimed to investigate the effects of incorporating dried tomato peel and seed flours into fresh acid cheese on its physicochemical, nutritional, and sensory properties. Five cheese samples were produced, including one control (CC:without peel and seed) and four experimental groups (CP1-%1peel and CP2-%5 peel; CS1-%1 seed and CS2- %5 seed). The samples were stored at +4 °C and analyzed for pH, total acidity, ash, dry matter, protein, total phenolic content, antioxidant activity (DPPH, ABTS), flavonoid content, color (*L**, *a**, *b**), and sensory characteristics. As a result of the analyses, fresh acid cheese samples was identified to have pH 4.53-6.01, titratable acidity 0.66-1.35 % lactic acid and ash values 1.42-1.65%. Cheese samples containing tomato seed and peel powder were found to have higher protein ratio than CC samples. The highest phenolic and antioxidant content (60.84 mg GAE/100 g), DPPH (13.49%) and ABTS (54.46 mg TEAC/100 g) were found in CP2 cheese containing 5% peel. Flavonoid contents of cheeses containing tomato powder were higher than CC cheeses. Cheeses containing peel powder showed increased *a** (redness) and *b** (yellowness) values, while *L** (lightness) values decreased with increasing peel concentration. According to the results of sensory analysis, the highest score for taste, color and general approval was identified for fresh acid cheese samples containing 5% peel powder. Tomato peel appears to have commercial potential thanks to the nutritional and sensory properties it adds to cheese production.

Key Words: Tomato, cheese, peel, seed, antioxidant

ÖZ

Bu çalışma, kurutulmuş domates kabuğu ve çekirdek tozlarının taze asitli peynire dahil edilmesinin fizikokimyasal, besinsel ve duyusal özellikleri üzerindeki etkilerini araştırmayı amaçlamıştır. Bir kontrol (CC: kabuk ve çekirdek içermeyen) ve dört deney grubu (CP1-%1 kabuk and CP2-%5 kabuk ; CS1-%1 çekirdek ve CS2- %5 çekirdek) olmak üzere beş peynir örneği üretilmiştir. Örnekler +4°C'de muhafaza edilerek pH, toplam asitlik, kül, kuru madde, protein, toplam fenolik madde miktarı, antioksidan aktivite (DPPH, ABTS), flavonoid miktarı, renk (*L*, a*, b**) ve duyusal özellikler açısından analiz edildi. Analizler sonucunda taze asitli peynirin pH'sının 4.53-6.01, titre edilebilir asiditesinin % 0.66-1.35 laktik asit ve kül değerlerinin %1.42-1.65 olduğu belirlendi. Domates çekirdeği ve kabuk tozu içeren peynir örneklerinin, CC örneklerine göre daha yüksek protein oranlarına sahip olduğu bulundu. En yüksek fenolik ve antioksidan içerik (60.84 mg GAE/100 g), DPPH (%13.49) ve ABTS (54.46 mg TEAC/100 g), %5 kabuk içeren CP2 peynirinde bulunmuştur. Domates tozu içeren peynirlerin flavonoid içerikleri kontrol peynirlerinden daha yüksek bulunmuştur. Kabuk tozu içeren peynirlerde *a** (kırmızılık) ve *b** (sarılık) değerleri artarken, *L** (açıklık) değerleri kabuk konsantrasyonunun artmasıyla azalmıştır. Duyusal analiz sonuçlarına göre, tat, renk ve genel onay açısından en yüksek puan %5 kabuk tozu içeren taze asitli peynir örneklerinde belirlenmiştir. Domates kabuklarının peynir üretimine kattıkları besinsel ve duyusal özellikler sayesinde ticari potansiyele sahip olduğu görülmektedir.

Anahtar Kelimeler: Domates, peynir, kabuk, çekirdek, antioksidan

Introduction

Tomatoes (*Lycopersicon esculentum*) are one of the most cultivated vegetables around the world with nearly 180 million tons of production. Fruit and vegetables have the highest wastage rates (~45%) among different consumable food products globally (Tarchi et al., 2024). As cultivation involves seasonal production and tomatoes are perishable, only some are consumed as fresh products (FAO, 2019). Industrial tomato processing produces large amounts of waste (Bhatkar et al., 2021). Among this waste material are tomato peels and seeds (Rajan et al., 2022). Tomato processing results in the production of tomato pulp comprising 60% seeds and 40% peel. Tomato seeds contain the nutrient compounds of proteins (32%), total fat (27%) and fiber (18%) (Gebeyew, 2014; Lu et al., 2019). Seed waste forms during the processing of tomato-based products and is a rich source of nutrients such as proteins, dietary fiber, tocopherols, phytosterols, and polyphenols, which have nutraceutical potential (Sarkar & Kaul, 2014). Considering this superior nutrient and nutraceutical infrastructure, tomato seeds may be applicable as an active agent in developing functional foods (Kumar et al., 2021). Tomato peels offer high fiber values (41%) and significant amounts of protein (14%), with a fat content of only 3% (García Herrera et al., 2010). Tomato peels may be used as a cheap source of soluble dietary fiber, accepted as being a functional compound with high value (Grassino et al., 2016). In addition to the high fiber content, the bioactive compounds found in tomato peels are interesting due to their antioxidant and coloring features. These compounds are carotenoids, phenolic compounds, vitamins and glycoalkaloids are included among these compounds (D'Ambra et al., 2023). These compounds are highly interesting due to features like anti-cancerogenic, cardioprotective, antimicrobial, anti-inflammatory and antioxidant potential (Viuda-Martos et al., 2014). According to FAOSTAT data, globally tomato production continuously increased in the 1994-2016 period. Tomatoes play an important role in the Turkish diet, and Turkey ranks fourth in global tomato production (for both fresh consumption and processing) following China, the USA, and India (Bakir et al., 2020). Though many gardening and food wastes are commonly used in the production of innovative products, there is still an important gap (Soleimanian et al., 2023). Food by-products are important in terms of reducing environmental problems and industrial costs (Lario et al., 2004). Although certain thermolabile nutrients may degrade during drying, the process also concentrates bioactive components and reduces antinutritional and allergenic factors, depending on the method used (Bhatkar et al., 2021). Fresh acid cheeses are defined as ready-to-eat cheese varieties produced by coagulating milk, cream or whey by acidification or a combination of acid and heat (Guinee et al., 1999). Cheese is a widely consumed dairy product rich in nutrients and serves as an excellent matrix for the incorporation of bioactive compounds. Recent research has focused on enhancing the nutritional and functional properties of cheese through the addition of plant-based components such as fiber, polyphenols, and antioxidants (Ritota & Manzi, 2020). Several studies were performed with the aim of using dried tomato wastes (D'Ambra et al., 2023; Grassino et al., 2016; Solhi et al., 2020). These studies showed they could be added to several products like meat products, bread, pasta and biscuits, which were not affected by technological features and had high sensory acceptability. Thus, in addition to enriching these products in terms of nutrients, they were reported to have higher antioxidant activity and storage stability due to containing phenolic compounds (Souza da Costa et al., 2023). Currently, interest is increasing in studies performed about the bioactive and health features of tomato by-products (Souza da Costa et al., 2023). Several studies have been performed on the potential to include plant-derived by-products in the human diet (Shan et al., 2011). The addition of natural bioactive compounds to cheese may develop nutrient, functional and sensory features (Ritota & Manzi, 2020). The use of tomato powder as a compound in processed cheese formulations may produce a final product with high antioxidant activity and better functional features, in addition to sensory features (Solhi et al., 2020). Studies about the sensory features of the dried form of tomato are limited and this situation leads to a broad scope for studies about consumer acceptance of dried forms in the future. The addition of tomato peels to fresh acid cheese may provide a healthier product due to both antioxidant bioactive compounds and fiber contained in this by-product of tomato processing. This study aimed to determine the effects of tomato waste on the chemical, textural and sensory features of fresh acid cheese.

Materials and methods

Material

Tomato peel and seed flour production

Tomatoes were sourced from a local market in Istanbul (cultivar: Rio Grande, conventional farming), and raw milk was supplied by Akar Dairy Company (Istanbul, Turkey). In cheese production, commercial cheese microbial protease (1% v/v) (Super Yeast, Intermak), which is a natural microbial protease obtained from fungal microorganisms isolated from plants (Mucor pusillus 1%), was used and NaCl (2% w/w) was added. Before starting cheese production, the seeds and peels of the tomatoes were dried in the drying oven (Binder ED240, Germany) at 60°C for 24 hours. The dried peels and seeds were ground into fine powder in a laboratory grinder (Waring, USA) and stored at 4 °C until further use. DPPH (2,2-Diphenyl-1 picrylhydrazyl), ABTS (2,2′-Azino-bis(3-ethylbenzothiazoline-6-sulphonic)), Folin–Ciocalteu reagent, chemicals and all solvents used for spectrophotometer and other analyses were purchased from Sigma-Aldrich (St. Louis, MO, USA).

Cheese production

Raw milk was pasteurized at 85°C for 15 minutes, then cooled to 35°C in a water bath and transferred into five separate one-liter jars. First, dried and powdered peel and seed samples, at 1% and 5%, were placed in the jars and mixed until homogeneously dispersed. Commercial microbial protease (1% v/v) was then added, the lids were closed, the jars were wrapped in a cloth to retain heat, and the jars were allowed to coagulate for (35ºC) two hours. Fresh acid cheese production is given in Figure 1. The resulting curd was filtered through cheese cloth for 24 hours. The resulting fresh acid cheese was dry-salted at 2% (w/w) and placed in plastic boxes to set. It was stored at +4°C (Samelis, J. et al., 2021). The control cheese (CC) without any tomato seed and peel flour was also prepared. For clarity, the cheeses supplemented with by-products are labelled as following: CP1 (cheese enriched with 1% dried tomato peel flour), CP2 (cheese enriched with 5% dried tomato peel flour), CS1 (cheese enriched with 1% dried tomato seed flour) and CS2 (cheese enriched with 5% dried tomato seed flour).

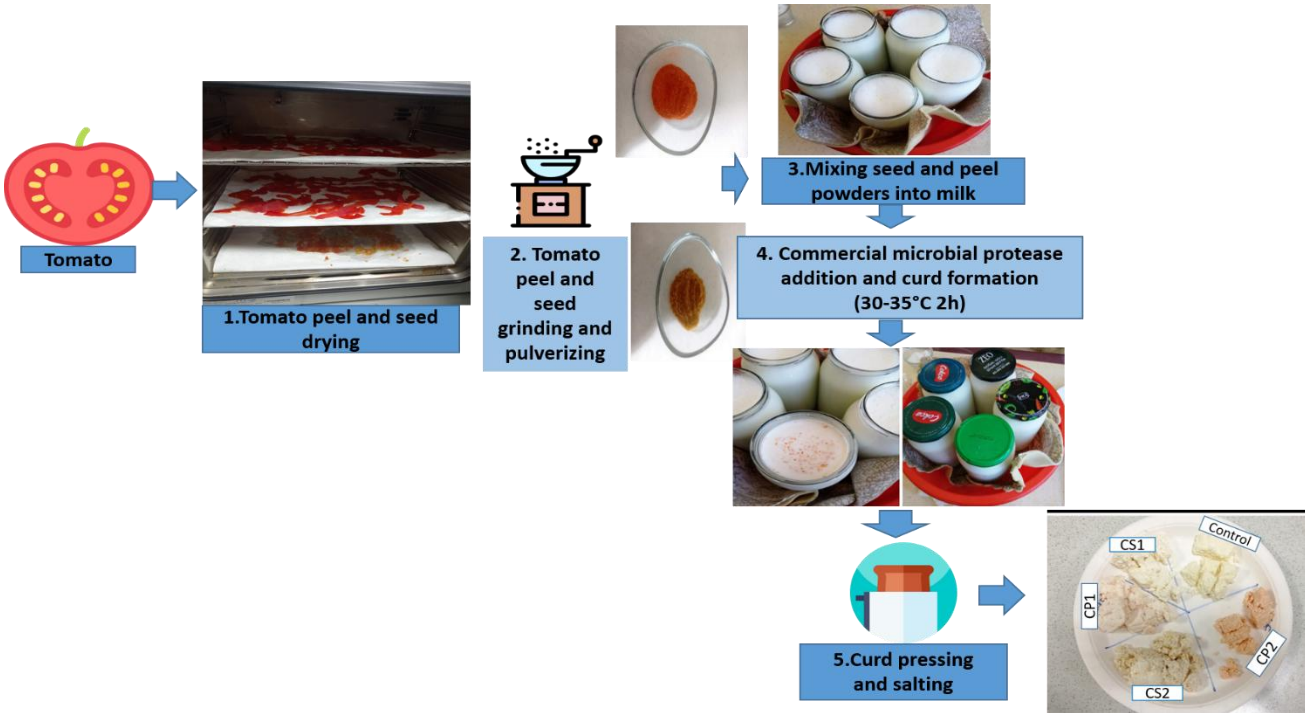

Figure 1. Fresh acid cheese production

Chemical Analyses

The pH of cheese samples was determined by inserting the PC glass electrode of a digital pH meter (INOLAB, WTWC pH 720) in samples (Marshall, 1992). For dry matter analysis, cheese samples were dried in a laboratory oven (Protherm PLF 110, Turkey) set at 105°C for 4 hours (AOAC, 1990). Ash content was determined by ashing cheese samples in an ash oven (Protherm, PLF 110/10, Turkey) at 550 °C according to AACC (2000). Total protein content were calculated by multiplying the nitrogen amount found with the Kjeldahl method by 6.38 factor (IDF, 2004). All experiments and analyses were conducted in triplicate (n = 3) for each cheese group.

Extraction of Cheese Samples

The extraction method was applied by modifying by Kaur & Kaur, (2018). Cheese samples were crushed via a laboratory grinder, mixed and homogenized with ultraturax using 70% methanol solution (10%, w/v) for 5 min. They were mixed in a mechanical mixer for 1 hour and left in an ultrasonic water bath (Protech, Turkey) at 25 C for 30 min, then centrifuged (Hetlich, England) for 15 min at 4000 rpm. The supernatant was removed and stored at +4 °C for spectrophotometric analysis.

Determination of Total Phenolic Content (TPC)

The TPC method was applied by Singleton et al., (1999). Firstly, 0.5 mL of cheese sample extract was mixed with 2.5 mL of Folin-Ciocalteu reagent (0.2 N) and 2 mL of Na_2CO_3 (7%) and kept in the dark for 30 min at 25 °C. Then, absorbance of the samples was measured with a UV spectrophotometer at a wavelength of 760 nm (Shimadzu UV 1800; Kyoto, Japan (Singleton et al., 1999). The TPC of the samples was calculated with formula y=9.9837X-0.0058 with a linear standard curve range (r^2 = 0.994). TPC results were expressed as mg gallic acid equivalent (GAE) per 100 grams of sample. All experiments and analyses were conducted in triplicate (n = 3) for each cheese group.

Antioxidant Analysis

DPPH Method

The antioxidant activity of the cheese samples extract was analyzed using DPPH (2,2-diphenyl-1-picrylhydrazyl). 250 µL of each homogenized sample extract was added to 3 mL 60 µM DPPH solution in ethanol. The absorbance of the samples incubated in the dark for 20 min was measured with a UV spectrophotometer set to 517 nm (Apostolidis et al., 2007). DPPH radical scavenging activity of the samples was calculated according to the following formula:

$$\text{DPPH Inhibition } (\%) = (\text{AC} - \text{AS}) / \text{AC} \times 100$$

Where AC is the absorbance of the control and AS is the absorbance of the sample. All experiments and analyses were conducted in triplicate (n = 3) for each cheese group.

ABTS Method

The inhibition of cheese samples against ABTS radical was carried out according to Re et al. (1999) method. 2,2′-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid radicals ($ABTS^+$) 7 mM ABTS stock solution containing 2.45 mM potassium persulfate was prepared and the mixture was kept in the dark at room temperature for 12–16 h. ABTS stock solution was diluted with water, and its absorbance was adjusted to 0.7, thus obtaining the ABTS working solution. 100 µL of cheese samples extract was added to 2 mL of ABTS working solution and incubated at 30 °C for 10 min in the dark. The method is based on the ability of antioxidants in the sample to neutralize the ABTS radical cation, leading to a decrease in absorbance measured at 734 nm. ABTS scavenging ability of samples was calculated using a standard calibration curve and expressed as mg/100g (Re et al. 1999). All experiments and analyses were conducted in triplicate (n = 3) for each cheese group.

Total Flavonoid Analysis

It was carried out based on the Zhishen method (1999). 0.25 mL of cheese extracts were mixed with 1.25 mL of distilled water, and then 75 µL of 5% sodium nitrite ($NaNO_2$) solution was added. Then, 150 µL of 10% aluminium chloride ($AlCl_3$) solution was added to each sample and incubated for 5 min. To terminate the reaction, 0.5 mL of 1 M sodium hydroxide (NaOH) solution and 275 µL of additional distilled water were added. Extracts were measured at 510 nm and calculated using a standard calibration curve. The results were expressed as mg catechin equivalent (CE)/g dry matter. All experiments and analyses were conducted in triplicate (n = 3) for each cheese group.

Color Analyses

Color parameters of the samples, including *L** (lightness), *a** (redness), and *b** (yellowness), were measured via a chroma meter (Konica-Minolta, CR-400, Osaka, Japan) and reported as mean ± standard deviation. The *a** value is an indicator of green (–) and red (+), whereas *b** is an indicator of blue (–) and yellow (+). All measurements were conducted in triplicate (n = 3) for each cheese group.

Sensory Analysis

A panel comprising 15 selected evaluators assessed the processed cheese samples using the method of Macku et al. (2008). Sensory analysis was conducted using a five-point hedonic scale (1 = dislike extremely, 5 = like extremely). The sensory form is given in Table 3. Panelists (n = 15) evaluated the samples in terms of color, appearance, texture, taste, and overall acceptability. A standardized evaluation form was provided to ensure consistency. The sensory analysis evaluation form is provided as a supplementary table after references list.

Statistical analysis

One-way analysis of variance (ANOVA) was performed using IBM SPSS Statistics 22 to assess significant differences among the sample groups (IBM SPSS Statistics 22). Multiple comparison tests related to all mean main effects were completed at 5% significance level with the Duncan test.

Discussion

Chemical Features of Cheese Samples

The results of the study indicate significant changes in the physicochemical properties of the different cheese samples (Table 1).

Table 1. Physicochemical properties of fresh acid cheeses

Samples	Dry matter (%)	Ash (%)	Protein (%)	pH	TA (% (lactic acid)
CC	44.28±0.76^{b}	1.42±0.03^{c}	17.05±0.51^{c}	5.82±0.00^{b}	0.9±0.02^{b}
CS1	47.98±0.91^{ab}	1.44±0.01^{c}	23.89±1.11^{b}	6.01± 0.00^{a}	0.62±0.02^{d}
CS2	49.94±1.05^{a}	1.48±0.01^{bc}	34.71±2.51^{a}	5.71±0.00^{c}	0.68±0.02^{cd}
CP1	46.45±0.85^{ab}	1.59±0.00^{b}	17.70±0.31^{c}	5.59±0.00^{d}	0.77±0.02^{c}
CP2	47.12±0.88^{ab}	1.65±0.01^{a}	26.73±1.42^{b}	4.53±0.00^{e}	1.35±0.03^{a}

a–e: Data in columns with different superscripts are significantly different. Cheeses enriched with tomato peels and seed: CC: control, CS1: 1 % seed, CS2: 5 % seed, CP1: 1 % peel, CP2: 5 % peel, TA: titratable acidity

Changes in dry matter (%), ash (%), protein, pH and titratable acidity (TA) content (%) with the addition of dried tomato peels and seeds compared to CC cheese samples are given in Table 1. Dry matter content varies between 44.28–49.94%. The dry matter content of cheeses containing tomato peel and seed flours was determined to be higher than that of CC cheeses. The highest dry matter content was determined in CS2 samples. Ash value varies between 1.42-1.65%. The highest ash content was found in CP2 cheeses, while the lowest was found in CCand CS1 cheeses. Adding tomato peel flour to cheese increased the ash value. Tomato peels are considered a good source of minerals and have been reported to have higher ash values than seeds (Weyh et al., 2022). The increase in dry matter and ash value observed in this study aligns with findings from similar studies showing that the addition of plant-based by-products leads to higher mineral and fiber content in cheese. Similar findings have been reported in studies where tomato by-products, such as seeds, enriched tarhana with minerals (Isik & Yapar, 2017), and the inclusion of tomato pulp in bread and muffins increased their mineral content (Mehta et al., 2018). Increasing the mineral content of tomato peels and seeds may be important in terms of increasing the mineral content in cheese production. Protein content in cheese samples varies between 17.05-34.71%. Statistically significant differences were detected in the protein values of all cheese samples except for the CP1 sample ($p<0.05$). While the CS2 group exhibited the highest protein content, the lowest was determined in the CC and CP1 cheeses ($p<0.05$). Higher protein content was determined in cheeses enriched with tomato peel and seed flour compared to the CC sample, except for sample CS1. Similar findings have been reported in the literature. For instance, Mehta et al. (2018) demonstrated that incorporating tomato pomace into muffins significantly improved their protein and fiber content. Szabo et al. (2018) reported that tomato by-products enhanced the nutritional properties of extruded cereal snacks by increasing their protein density (Ritota & Manzi, 2020; Szabo et al., 2018). Unlike tomato peels, tomato seeds are rich in protein (Lu et al., 2019). Cheese sample CS2 enriched with 5% tomato peel had the highest protein content and this increase was statistically significant ($p <0.05$). This result suggests that tomato components could have a protein-enriching effect. Similar findings are supported by other studies, which indicate that the use of industrial tomato by-products improves the protein profile of various foods (Szabo et al., 2018). The addition of tomato peel generally reduced the pH of cheese samples due to its acidic nature; however, this trend was not consistent across all samples, as the CS1 sample (1% seed) showed a higher pH than the CC sample, likely due to lower organic acid content in seeds. On the other hand, the addition of tomato peels increased the pH, and as the amount of peel increased, the TA decreased. Similarly, the addition of tomato peel to Primosale cheese did not cause a significant change compared to the control sample (Costa et al., 2018). The CP2 sample, with the highest TA and the lowest pH values, demonstrated that tomato peel significantly affected the acidity profile of the cheese. The pH and acidity levels of tomato peel and seeds vary. Tomato peel generally exhibits a lower pH (4.2–4.6), while seeds are slightly less acidic, with a pH around 4.8–5.0 (Kaboré et al., 2022). This composition may explain the pH-lowering effect of peel-enriched samples, especially CP2, as shown in Table 1. This suggests that tomato peel can reduce the pH and increase the acidity of cheese. The literature indicates that functional components can enhance the fermentation capacity of cheese, increasing acidity levels (Difonzo et al., 2023).

Total Phenolic Content, Antioxidant and Flavanoid Content of Cheeses

In this study, the effects of adding dried tomato seeds and peel to fresh acid cheeses on total phenolic content (TPC), antioxidant activity (DPPH, ABTS), and flavonoid content were examined. The findings revealed significant differences across all analyses (Table 2), particularly inTPC, DPPH, ABTS, and flavonoid values.

Table 2. Total phenolic content (TPC), antioxidant activity (DPPH, ABTS) and flavonoid content of the fresh acid cheeses

Samples	TPC (mg GAE/100 g)	DPPH (% Inhibition)	ABTS (mg TEAC /100g)	Flavonoid (mg/g)
CC	23.92 ±0.60^{bc}	10.17±0.06^{e}	31.66±1.40^{d}	3.80±0.31^{c}
CS1	28.88 ±0.55^{cd}	10.39±0.08^{d}	43.06±0.2^{c}	5.06±0.69^{bc}
CS2	35.44±0.20^{bc}	10.67±0.04^{c}	49.54±1.4^{b}	5.88±0.15^{b}
CP1	40.5±0.05^{b}	11.49±0.04^{b}	50.96±1.3^{b}	5.97±0.46^{b}
CP2	64.84±0.96^{a}	13.49±0.04^{a}	54.46±0.4^{a}	8.02±0.37^{a}

a–e : Data in columns with different superscripts are significantly different. Fresh acid cheese enriched with tomato peels and seed; : CC: control, CS1: 1 % seed , CS2: 5 % seed , CP1: 1 % peel CP2: 5 % peel.

When evaluated in terms of TPC, significant increases were observed in the groups containing both tomato seeds and peel compared to the CC group. The CP2 group, which contained 5% tomato peel, had the highest phenolic content, reaching 64.84±0.96 mg GAE/100 g ($p < 0.05$). Similarly, in a study examining the total phenolic content of the seeds and peels of two tomato varieties (Petomech and F1 Mongal), the peel of both varieties was found to have a higher phenolic content, while the seeds had a lower content. The lowest value was found in the seeds of the Petomech variety, while the highest value was found in the peel of the same variety (Kaboré et al., 2022). This result indicates that the addition of tomato peel can effectively increase the concentration of phenolic compounds. In terms of DPPH radical scavenging activity, the CP2 group (5% tomato seeds) recorded the highest inhibition rate at 13.49±0.04%. In a study conducted on tomato peels and seeds, antioxidant content in the peels of Mongal and Petomach tomato species was determined to be higher in the peel than in the seeds according to DPPH and FRAP results. This high antioxidant capacity could be attributed to the content of antioxidants such as phenolics, carotenoids, and vitamin C (Kaboré et al., 2022). In contrast, the CC group had the lowest inhibition rate (10.17±0.06%). Regarding ABTS radical scavenging activity, the CP2 group had the highest value, determined to be 54.46±0.4 mg TEAC/100 g. The CC group exhibited the lowest ABTS activity (p>0.05). The antioxidant activity determined by DPPH and ABTS methods was higher in cheeses enriched with tomato peel flour than in cheeses containing seed flour. Peel-enriched fresh acid cheeses samples exhibited higher antioxidant values in all three assays, likely due to the concentration of phenolics and carotenoids present in tomato peel (Valdez-Morales et al., 2014).These differences suggest that the peel and seed samples respond differently to different radicals, and the quality of the extracted compounds varies (Valdez-Morales et al., 2014). Significant differences were found between the groups with tomato peel and seeds in terms of flavonoid content ($p < 0.05$). When examining flavonoid content, the highest value was recorded in the CP2 group (5% tomato peel) at 8.02±0.37 mg/g. In conclusion, these findings suggest that tomato seeds and peels are important sources of phenolic compounds, antioxidants, and flavonoid content and that they could be used as functional components in the production of fresh acid cheeses.

Color Properties of Cheese Samples

According to the results presented in the figure 2, the effects of adding tomato peel and seeds on the color values of fresh acid cheeses can be summarized as follows: The CC group exhibited the highest *L** (lightness) value, which decreased significantly in the groups with added tomato peel and seeds (Fig 2).

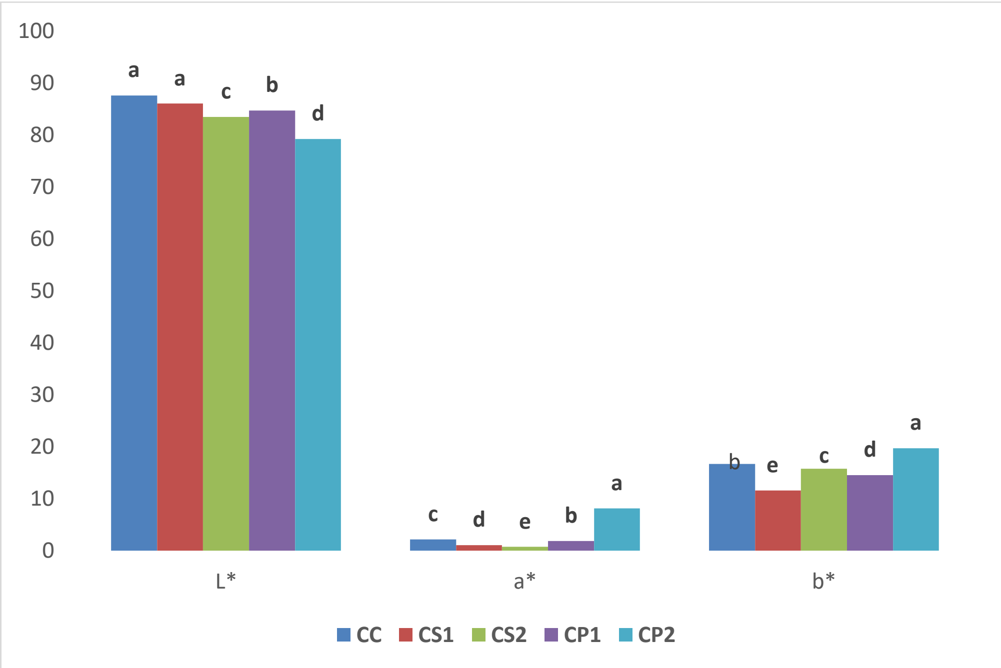

Figure 2. Color parameters (*L*, a*, b**) of control and tomato peel/seed-enriched Fresh acid cheeses. Cheeses enriched with tomato peels and seed ; CS1: 1 % seed, CS2: 5 % seed , CP1: 1 % peel , CP2: 5 % peel a–e : Data in columns with different superscripts are significantly different.

Specifically, the CP2 sample with 5% tomato peel had the lowest *L** value, suggesting that the addition of tomato peel reduces the lightness of the cheese. The *a** (redness) values showed significant increases in cheese samples with added tomato peel and seeds. The CP2 sample (5% tomato peel) had the highest *a** value, indicating that the peel and seeds impart a reddish color to the cheese. Similarly, the *b** (yellowness) values increased in the groups with added tomato peel and seeds. The highest *b** value was found in the CP2 sample (5% tomato peel). Similar changes in color values were observed in cheeses with added tomato by-products, which reduced the *L** value and increased the *a** and *b** values (Briones-Labarca et al., 2019).

The addition of tomato peel influenced the color attributes of the cheese, leading to a slight decrease in *L** values, indicating a darker appearance. However, sensory evaluation scores for color remained within acceptable ranges, suggesting that the visual changes did not negatively impact consumer preference. Similar findings were reported by Valdez-Morales et al. (2014), who noted that tomato peel incorporation affected the color parameters of food products but did not significantly alter consumer acceptance.

Sensory Properties

Sensory evaluation of the cheese samples (Fig.3) was conducted to assess specific attributes, including flavor, color, appearance, texture, and overall acceptability. Fig.4 presents the sensory analysis results of fresh acid cheeses samples.

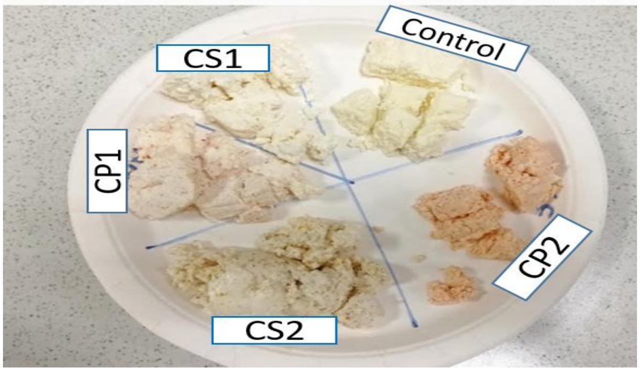

Figure 3. Cheeses containing tomato control, peels and seeds. Fresh acid cheeses enriched with tomato peels and seed; CC: control, CS1: 1 % seed, CS2: 5 % seed , CP1: 1 % peel, CP2: 5 % peel

A statistically significant difference was observed between the CC group and other samples in terms of taste ($p<0.05$). However, the CS1 sample received the lowest flavor score compared to the other samples (2.42±0.58). The highest flavor score was given to control, 1% and 5% peel fresh acid cheeses. In cheeses containing tomato peel flour, the rind color may have a positive effect on the taste. Similarly, no significant difference was found between the samples in terms of flavor. Statistical analysis of flavor showed no significant difference between groups ($P > 0.05$), confirming that the addition of tomato peel or seed had minimal impact on perceived flavor.

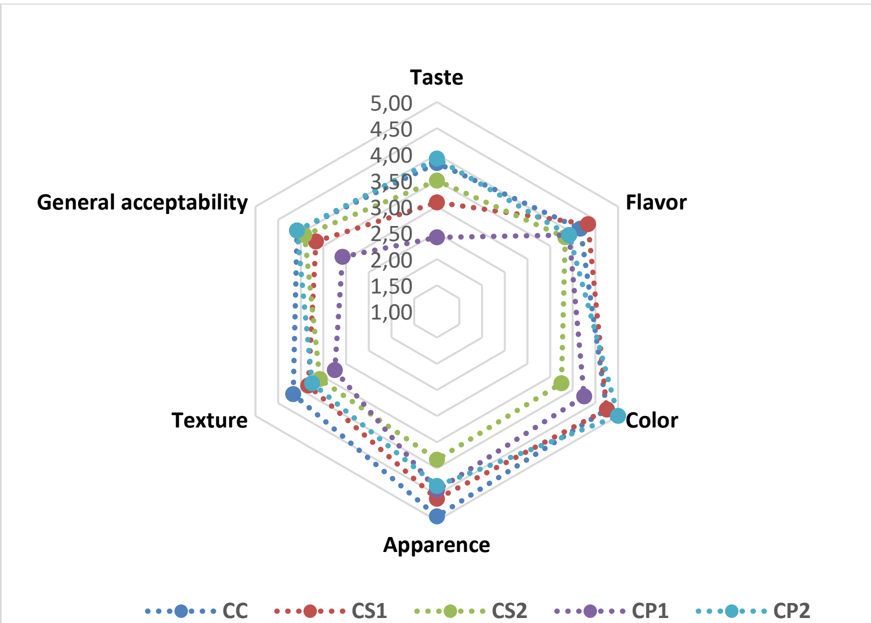

Figure 4. Sensory evaluation of the cheese samples.
Fresh acid cheeses enriched with tomato peels and seed; CC: control, CS1: 1 % seed, CS2: 5 % seed, CP1: 1 % peel, CP2: 5 %

peel

In terms of color, the CP2 sample (5.00±0.0) received the highest score, while the CS2 sample (3.75±0.0) received the lowest score. This result suggests that the addition of tomato peel may be less preferred in terms of color. Sensory evaluation revealed that the incorporation of tomato by-products did not significantly affect the overall appearance of the cheese samples. This aligns with previous studies indicating that the addition of tomato derivatives can be achieved without compromising the visual quality of dairy products (Mehta et al., 2018). The CP1 sample (1% tomato peel) received the lowest texture score (3.25±0.08), indicating a potential negative impact on texture at lower inclusion levels. However, the CP2 sample (5% tomato seed) exhibited improved texture scores (4.54±0.17), suggesting that higher concentrations of tomato seed may contribute positively to the textural properties of the cheese. This observation is consistent with findings by Szabo et al. (2018), who reported that the inclusion of tomato by-products at appropriate levels can enhance the texture of food products. This suggests that cheese with 5% tomato peel was generally preferred, but the addition of tomato seeds and peel at lower levels may have a negative impact on general acceptibility. These findings indicate that the use of tomato seeds and peel in cheese production can create complex effects on sensory properties, with variations in consumer preference depending on the amount of these components. For general acceptability, the CC group (4.08±0.25) and the CP2 sample (4.09±0.08) received the highest scores. This indicated that fresh acid cheese containing 5% tomato peel was generally preferred, although the addition of lower levels of tomato seeds and peel had a negative impact on general acceptibility. CP2 cheese scored similarly to the CC sample in terms of taste, flavor, color, appearance, texture and general acceptability, and it was determined that the high rind content positively affected consumer preference for cheese.

Conclusion

This study examined the effects of using dried tomato peel and seeds in fresh acid cheeses production on the physicochemical, antioxidant, and sensory properties of the cheese The addition of dried tomato peel and seed flour created differences in the dry matter, ash and protein content of fresh acidic cheese.Specifically, 5% tomato peel flour increased the % ash content, while 5% seed flour increased the % total protein content. In general, the addition of tomato peel and seed flour to cheese significantly increased the total phenolic, antioxidant, and flavonoid content compared to the control sample. In particular, the addition of 5% tomato seeds and peel (CS2 and CP2 groups) resulted in the highest values for phenolic content, flavonoids, and antioxidant activity, enhancing the functional properties of the cheese in terms of nutrition benefits. The findings suggest that dried tomato by-products have the potential to improve the nutritional value and sensory acceptability of fresh acid cheese. However, complex effects were observed in terms of sensory properties; while the addition of tomato seeds may have negatively affected flavor and texture, it improved the color and appearance. In conclusion, the use of dried tomato peel and seeds in fresh acid cheese production could be an effective method for utilizing valuable tomato waste and enhancing the nutritional and functional properties of cheese. However, given the complex effects of these components on sensory properties, their addition levels need to be optimized. Among all formulations, the CP2 sample (5% tomato peel) demonstrated the most favorable results in terms of antioxidant capacity, phenolic content, color, and general acceptibility, indicating its strong potential for functional of dairy product development. Future studies could further clarify the potential of this innovative approach by comprehensively examining the effects of different tomato varieties and processing methods on cheese.

Author Contributions

EC: Conceptualization, Methodology, Analysis, Investigation, Writing original draft, Review, supervision.
HB: Analysis, Review, Editing, Supervision
AC: Writing original draft, Review, Editing, Supervision
OS: Review, Editing, Supervision

Conflict of interest

This research did not receive any specific grant from funding agencies in the public, commercial or not-for-profit sectors. There is no conflict of interest to declare.

Acknowledgement

We would like to thank Yıldız Technical University, Department of Food Engineering, for providing us with the opportunity to work in their laboratory for some of the analyses of this study. We would also like to thank undergraduate student at Istanbul Aydın University, Department of Food Technology, İrem Çeşmeli, for helping us with the analyses.

References

AACC. (2000). Approved methods of the American Association of Cereal Chemists (10th ed.).

AOAC. (1990). Official Methods of Analysis, AOAC International. *Gaithersburg, MD*.

Apostolidis, E., Kwon, Y.-I., & Shetty, K. (2007). Inhibitory potential of herb, fruit, and fungal-enriched cheese against key enzymes linked to type 2 diabetes and hypertension. *Innovative Food Science & Emerging Technologies*, *8*(1), 46–54. https://doi.org/10.1016/j.ifset.2006.06.001

Bakir, S., Capanoglu, E., Hall, R. D., & de Vos, R. C. H. (2020). Variation in secondary metabolites in a unique set of tomato accessions collected in Turkey. *Food Chemistry*, *317*, 126406. https://doi.org/10.1016/j.foodchem.2020.126406

Bhatkar, N. S., Shirkole, S. S., Mujumdar, A. S., & Thorat, B. N. (2021). Drying of tomatoes and tomato processing waste: a critical review of the quality aspects. *Drying Technology*, *39*(11), 1720–1744. https://doi.org/10.1080/07373937.2021.1910832

Briones-Labarca, V., Giovagnoli-Vicuña, C., & Cañas-Sarazúa, R. (2019). Optimization of extraction yield, flavonoids and lycopene from tomato pulp by high hydrostatic pressure-assisted extraction. *Food Chemistry*, *278*, 751–759. https://doi.org/10.1016/j.foodchem.2018.11.106

Costa, C., Lucera, A., Marinelli, V., Del Nobile, M. A., & Conte, A. (2018). Influence of different by-products addition on sensory and physicochemical aspects of Primosale cheese. *Journal of Food Science and Technology*, *55*(10), 4174–4183. https://doi.org/10.1007/s13197-018-3347-z

D'Ambra, K., Minelli, G., & Lo Fiego, D. Pietro. (2023). Effect of hazelnut skin and dry tomato peel on the oxidative stability, chemical and sensory properties of pork burgers during refrigerated storage. *Food Packaging and Shelf Life*, *38*(June), 101107. https://doi.org/10.1016/j.fpsl.2023.101107

Difonzo, G., Antonino, C., Squeo, G., Caponio, F., & Faccia, M. (2023). Application of Agri-Food By-Products in Cheesemaking. *Antioxidants*, *12*(3) https://doi.org/10.3390/antiox12030660

Food and Agriculture Organization. (2019). FAO statistical databases agriculture: Food balances (2010-2019). Retrieved from https://www.fao.org/faostat/en/#data/FBS

García Herrera, P., Sánchez-Mata, M. C., & Cámara, M. (2010). Nutritional characterization of tomato fiber as a useful ingredient for food industry. *Innovative Food Science & Emerging Technologies*, *11*(4), 707–711. https://doi.org/10.1016/j.ifset.2010.07.005

Gebeyew, K. (2014). The Effect of Feeding Dried Tomato Pomace and Concentrate Feed on Body Weight Change, Carcass Parameter and Economic Feasibility on Hararghe Highland Sheep, Eastern Ethiopia. *Journal of Veterinary Science & Technology*, *06*(02). https://doi.org/10.4172/2157-7579.1000217

Grassino, A. N., Halambek, J., Djaković, S., Rimac Brnčić, S., Dent, M., & Grabarić, Z. (2016). Utilization of tomato peel waste from canning factory as a potential source for pectin production and application as tin corrosion inhibitor. *Food Hydrocolloids*, *52*, 265–274. https://doi.org/10.1016/j.foodhyd.2015.06.020

Guinee, T., Pudja, P., & Farkye, N. (1999). Fresh acid-curd cheese varieties. In *Cheese: Chemistry, Physics and Microbiology: Volume 2: Major Cheese Groups* (pp. 363-419). Springer.

IDF. (2004). Milk determination of nitrogen content ISO 8968-3-IDF 020-3. *International Dairy Federation, Brussels, Belgium*.

Isik, F., & Yapar, A. (2017). Effect of tomato seed supplementation on chemical and nutritional properties of tarhana. *Journal of Food Measurement and Characterization*, *11*(2), 667–674. https://doi.org/10.1007/s11694-016-9436-7

J. Zhishen, T. Mengcheng, W. Jianming, Research on antioxidant activity of flavonoids from natural materials. Food Chem. 64, 555–559 (1999)

Kaboré, K., Konaté, K., Sanou, A., Dakuyo, R., Sama, H., Santara, B., Compaoré, E. W. R., & Dicko, M. H. (2022). Tomato By-Products, a Source of Nutrients for the Prevention and Reduction of Malnutrition. *Nutrients*, *14*(14), 2871 https://doi.org/10.3390/nu14142871

Kaur, R., & Kaur, M. (2018). Microstructural, physicochemical, antioxidant, textural and quality characteristics of wheat muffins as influenced by partial replacement with ground flaxseed. *LWT*, *91*, 278-285.

Kumar, M., Tomar, M., Bhuyan, D. J., Punia, S., Grasso, S., Sá, A. G. A., Carciofi, B. A. M., Arrutia, F., Changan, S., Radha, Singh, S., Dhumal, S., Senapathy, M., Satankar, V., Anitha, T., Sharma, A., Pandiselvam, R., Amarowicz, R., & Mekhemar, M. (2021). Tomato (Solanum lycopersicum L.) seed: A review on bioactives and biomedical activities. *Biomedicine & Pharmacotherapy*, *142*, 112018. https://doi. org/10.1016/j.biopha.2021.112018

Lario, Y., Sendra, E., Garcıa-Pérez, J., Fuentes, C., Sayas-Barberá, E., Fernández-López, J., & Perez-Alvarez, J. A. (2004). Preparation of high dietary fiber powder from lemon juice by-products. *Innovative Food Science & Emerging Technologies*, *5*(1), 113-117. https://doi.org/10.1016/j.ifset.2003.08.001

Lu, Z., Wang, J., Gao, R., Ye, F., & Zhao, G. (2019). Sustainable valorisation of tomato pomace: A comprehensive review. *Trends in Food Science & Technology*, *86*, 172–187. https://doi.org/10.1016/j.tifs.2019.02.020

Macků, I., Buňka, F., Pavlínek, V., Leciánová, P., & Hrabě, J. (2008). The effect of pectin concentration on viscoelastic and sensory properties of processed cheese. International Journal of Food Science and Technology, 43(9), 1663-1670.

Marshall, R. T. (1992). Standard methods for the examination of dairy products. *American Public Health Association. Washington D.C.*

Mehta, D., Prasad, P., Sangwan, R. S., & Yadav, S. K. (2018). Tomato processing byproduct valorization in bread and muffin: improvement in physicochemical properties and shelf life stability. *Journal of Food Science and Technology*, *55*(7), 2560–2568. https://doi.org/10.1007/s13197-018-3176-0

Rajan, A., Kumar, S., Sunil, C. K., Radhakrishnan, M., & Rawson, A. (2022). Recent advances in the utilization of industrial byproducts and wastes generated at different stages of tomato processing: Status report. *Journal of Food Processing and Preservation*, *46*(11). https://doi.org/10.1111/jfpp.17063

R. Re, N. Pellegrini, A. Proteggente, A. Pannala, M. Yang, C. Rice-Evans (1999). Antioxidant activity applying an improved ABTS radical cation decolorization assay. Free Radic. Biol. Med. 26(9– 10), 1231–1237

Ritota, M., & Manzi, P. (2020). Natural Preservatives from Plant in Cheese Making. *Animals*, *10*(4), 749. https://doi.org/10.3390/ani10040749

Shan, B., Cai, Y.-Z., Brooks, J. D., & Corke, H. (2011). Potential Application of Spice and Herb Extracts as Natural Preservatives in Cheese. *Journal of Medicinal Food*, *14*(3), 284–290. https://doi.org/10.1089/jmf.2010.0009

Samelis, J., Doulgeraki, A. I., Bikouli, V., Pappas, D., & Kakouri, A. (2021). Microbiological and metagenomic characterization of a retail delicatessen Galotyri-like fresh acid-curd cheese product. Fermentation, 7(2), 67.

Sarkar, A., & Kaul, P. (2014). Evaluation of Tomato Processing By-Products: A Comparative Study in a Pilot Scale Setup. *Journal of Food Process Engineering*, *37*(3), 299–307. https://doi.org/10.1111/jfpe.12086

Singleton, V. L., Orthofer, R., & Lamuela-Raventós, R. M. (1999). [14] Analysis of total phenols and other oxidation substrates and antioxidants by means of folin-ciocalteu reagent. In *Methods in Enzymology* (Vol. 299, pp. 152-178). Academic Press. https://doi.org/https://doi.org/10.1016/S0076-6879(99)99017-1

Soleimanian, Y., Ratti, C., Karim, A., Rodrigue, D., & Khalloufi, S. (2023). Simultaneous valorization of discarded tomato and whey through osmotic dehydration: Development of high value-added products, rheological characterizations, and mass transfer modeling. *Journal of Food Engineering*, *359*, 111713. https://doi.org/10.1016/j.jfoodeng.2023. 111713

Solhi, P., Azadmard-Damirchi, S., Hesari, J., & Hamishehkar, H. (2020). Production of the processed cheese containing tomato powder and evaluation of its rheological, chemical and sensory characteristics. *Journal of Food Science and Technology*, *57*(6), 2198–2205. https://doi.org/10.1007/s13197-020-04256-1

Souza da Costa, B., García, M. O., Muro, G. S., & Motilva, M. J. (2023). A comparative evaluation of the phenol and lycopene content of tomato by-products subjected to different drying methods. *Lwt*, *179*(March). https://doi.org/10.1016/j.lwt.2023.114644

Szabo, K., Cătoi, A. F., & Vodnar, D. C. (2018). Bioactive Compounds Extracted from Tomato Processing by-Products as a Source of Valuable Nutrients. *Plant Foods for Human Nutrition*, *73*(4), 268–277. https://doi.org/10.1007/s11130-018-0691-0

Tarchi, I., Boudalia, S., Ozogul, F., Câmara, J. S., Bhat, Z. F., Hassoun, A., Perestrelo, R., Bouaziz, M., Nurmilah, S., Cahyana, Y., & Aït-Kaddour, A. (2024). Valorization of agri-food waste and by-products in cheese and other dairy foods: An updated review. *Food Bioscience*, *58*, 103751. https://doi.org/10.1016/j.fbio.2024.103751

Weyh, C., Krüger, K., Peeling, P., & Castell, L. (2022). The role of minerals in the optimal functioning of the immune system. *Nutrients*, *14*(3), 644.

Valdez-Morales, M., Espinosa-Alonso, L. G., Espinoza-Torres,

L. C., Delgado-Vargas, F., & Medina-Godoy, S. (2014). Phenolic content and antioxidant and antimutagenic activities in tomato peel, seeds, and byproducts. *Journal of Agricultural and Food Chemistry*, *62*(23), 5281–5289. https://doi.org/10.1021/jf5012374

Viuda-Martos, M., Sanchez-Zapata, E., Sayas-Barberá, E., Sendra, E., Pérez-Álvarez, J. A., & Fernández-López, J. (2014). Tomato and Tomato Byproducts. Human Health Benefits of Lycopene and Its Application to Meat Products: A Review. *Critical Reviews in Food Science and Nutrition*, *54*(8), 1032–1049. https://doi.org/10.1080/10408398.2011.623799

Table 3. Sensory analysis form

<table>
<tr><td></td><td></td><td colspan="6">Sensory Test</td></tr>
<tr><td></td><td></td><td colspan="6">Name and Surname of the Panelist : Date:
Product: Cheese</td></tr>
<tr><td></td><td></td><td colspan="6">Dear Panelists;
Please rate the cheese samples we offer you with codes 158, KXN, 71BE, A6C, 178 separately by evaluating taste flavor, color, taste, color, appearance, texture and your general acceptability of that product, according to the score scale below, from 1 to 5.</td></tr>
<tr><td rowspan="2">Samples Codes</td><td colspan="2"></td><td></td><td colspan="3"></td></tr>
<tr><td>Taste</td><td>Flavor</td><td>Color</td><td>Appearance</td><td>Texture</td><td>General Acceptability</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="7">Point Scale</td></tr>
<tr><td colspan="7">1: Very bad, 2: bad, 3: neither very good nor bad 4: Good, 5: Very good</td></tr>
</table>