UFT Academic Publishing House, Plovdiv

Food Science and Applied Biotechnology
e-ISSN: 2603-3380

Journal home page: www.ijfsab.com
https://doi.org/10.30721/fsab2026.v9.i1



CC BY SA

OPEN ACCESS

Review Article

Plant agro-food by-products as functional additives in dairy products: a review

Milena Dimitrova-Dicheva[1,3], Tatyana Balabanova[1,3], Petya Boyanova[1,3], Ivelina Ivanova[2,3], Mihaela Ivanova[1,3]✉, Alexandar Balabanov[1,3]

[1]*Department of Milk and Dairy Technology, Technological Faculty, University of Food Technologies, Plovdiv, Bulgaria*
[2]*Department of Analytical Chemistry and Physical Chemistry, Technological Faculty, University of Food Technologies, Plovdiv, Bulgaria*
[3]*Center of Competence AgriFoodSystems and Bioeconomy, 4000 Plovdiv, Bulgaria, Bulgaria*

Abstract
In recent years, there has been a growing focus on food waste and by-products, primarily due to the diminishing availability of food resources and the detrimental ecological impact of contemporary production and consumption practices. This focus applies to a wide range of foodstuffs, including dairy products, of which cheese is a particularly popular and widely consumed item on a global scale. Consequently, cheese and other dairy products can serve as effective vehicles for the valorization of food waste and by-products. The incorporation of plant by-products into yogurt and cheese formulations has been shown to enhance yield, water retention, total phenolic content, and antioxidant activity, although effects on texture may vary. This review focuses on opportunities to valorize various food waste streams in the dairy sector, especially in cheese and yogurt. Furthermore, it emphasizes the significance of recovered bioactive, added-value compounds in enhancing the nutritional, technological, and sensory properties of dairy products. It is hypothesized that food waste, with a focus on tomato and carob by-products, could be utilized in the future to enhance the functionality of dairy products.

Keywords
tomato, carob, agro waste, fermented milk, fresh cheese, matured cheese

Abbreviations
CE – circular economy; CFU – colony-forming unit; DM – dry matter; DPPH – 2,2-diphenyl-1-picrylhydrazyl; GAE – gallic acid equivalents; SDGs – United Nations Sustainable Development Goals

✉*Corresponding author: Assoc. Prof. Mihaela G. Ivanova, PhD, Department of Milk and Dairy Technology, Technological Faculty, University of Food Technologies, Center of Competence AgriFoodSystems and Bioeconomy, 4000 Plovdiv, Bulgaria, 26 Maritza Blvd., 4002 Plovdiv, Bulgaria, tel.: +359 32 603 762; e-mail: mivanova@uft-plovdiv.bg*

Article history:
Received 20 January 2026
Reviewed 20 February 2026
Accepted 23 February 2026
Available on-line 18 March 2026

https://doi.org/10.30721/fsab2026.v9.i1.656
2026, UFT Academic publishing house, Plovdiv

Introduction

The contemporary agro-food system generates substantial quantities of plant-based by-products at every stage of the supply chain, from primary agricultural production to industrial processing. These residues, including fruit and vegetable pomaces, peels, seeds, husks, whey, and other residual materials, are often treated as low-value waste (Castillejo and Martínez-Zamora 2024). Disposal, traditionally through landfilling or incineration, imposes a significant environmental burden due to greenhouse gas emissions, soil and water contamination, and the loss of bioactive compounds with potential nutritional and functional value (Šelo et al. 2021). Approximately one-third of all food produced worldwide is lost or wasted across the supply chain, with industrial processing by-products accounting for a considerable share of these losses (Carnaval et al. 2024).

Numerous studies emphasize that the linear "take-make-dispose" production model imposes heavy burdens through resource depletion, waste generation, and greenhouse gas emissions. For example, fruit by-products may account for more than 50% of the mass of fresh food inputs and are often landfilled, resulting in environmental and economic impacts (Priyanka et al. 2024). In this context, the circular economy (CE) has gained prominence in agro-food systems. By recirculating by-products into value-added uses, reducing waste, and closing material loops, CE strategies aim to promote sustainable development at the intersection of economy, environment, and society (Hamam et al. 2021). Recent reviews note that agro-food by-product valorization aligns directly with the United Nations Sustainable Development Goals (SDGs) by enabling more efficient resource use, mitigating environmental burdens, and creating new revenue streams (Ligarda-Samanez et al. 2025).

Sustainable management of agro-food by-products is increasingly recognized as a key strategy within the circular economy and sustainable development frameworks (Ligarda-Samanez et al. 2025). Valorizing these residues as value-added ingredients promotes resource efficiency, reduces environmental impact, and creates economic opportunities by transforming low-value waste streams into functional compounds with potential applications in food systems (Matei et al. 2021; Ahmad 2024).

Plant-derived agro-food by-products are rich in dietary fiber, polyphenols, flavonoids, proteins, pigments, and other bioactive compounds that can serve as functional ingredients in food systems (Ligarda-Samanez et al. 2025). Numerous studies have shown that extracts or powders from fruit, vegetable, and cereal by-products possess antioxidant, antimicrobial, prebiotic, and texture-modifying properties that can enhance the quality and safety of formulated foods (Iriondo-DeHond et al. 2018; Sagar et al. 2018). Incorporating these compounds into the dairy matrix offers a dual benefit: improving the nutritional and functional properties of dairy products while contributing to the sustainable valorization of agro-industrial residues. Several studies have highlighted the potential of plant by-products to improve the textural, sensory, and bioactive properties of food products, supporting their integration into functional food formulations (Rațu et al. 2023).

The dairy industry, which is one of the most widely consumed and economically significant food sectors, has embraced functional innovation as a key trend (Martins et al. 2019). Dairy products are an important source of functional ingredients because of their inherent nutritional profile, including high-quality proteins (caseins and whey proteins), bioactive peptides, and minerals such as calcium (Elkot and Ismail 2025). Modern consumers increasingly seek dairy foods that not only provide essential nutrients but also confer additional health benefits, such as antioxidant protection, gut health support, and metabolic regulation (Granato et al. 2020). Incorporating plant-based by-products into dairy-based systems, such as yogurt, cheese, fermented milk, and ice cream, has gained attention for its ability to enhance nutritional profile, increase bioactive content, modify textural properties, and contribute to natural preservation (Roxana et al. 2025; Sukhikh et al. 2019).

Recent research has evaluated components derived from fruit peels, grape pomace, olive leaves, pomegranate rind, cereal bran, and other by-products as promising additives in both fresh and matured dairy systems. These studies report improvements in antioxidant activity, phenolic content, color stability, water-holding capacity, microbial inhibition, and sensory acceptability, though challenges remain in standardization, regulatory approval, and large-scale processing (Tarchi et al. 2024).

Despite growing research interest, a comprehensive synthesis of how various agro-food by-products have been applied as functional additives in dairy products is still needed. Prior work highlights the potential of food by-products for broader food applications, yet relatively few studies consolidate evidence on dairy-specific outcomes, techno-functional effects, and industrial applicability. Given the widespread consumption of dairy across all demographic sectors, exploring such valorization pathways offers tangible benefits for nutrition, economic development, and environmental sustainability (Tarchi et al. 2024).

A summary of scientific developments and an assessment of opportunities for incorporating plant by-products into fresh and matured dairy products are presented in Fig. 1.



Figure 1. Utilization of plant agro-food by-products (Figure created using the authors' original text with visualization support from ChatGPT (OpenAI))

Therefore, this review aims to provide a comprehensive synthesis of current research on the valorization of plant-derived agro-food by-products as functional ingredients in dairy applications, with a special focus on tomato and carob by-products. Specifically, the objectives are to: (i) critically analyze strategies for recovering and incorporating plant by-products into fresh and aged dairy products; (ii) evaluate the economic, ecological, and technological opportunities and challenges associated with their use; and (iii) discuss perspectives for industrial-scale implementation. By integrating insights from recent literature, this review seeks to elucidate how upcycling plant-based by-products can simultaneously support circular economy principles, reduce food waste, and foster innovation in functional dairy product development.

Valorization of plant agro-food by-products

Plant by-products from the agro-food industry. During the processing of fruits, vegetables, cereals, and legumes, substantial quantities of plant-derived by-products are generated. These residues are traditionally considered waste, but they are increasingly recognized as valuable secondary raw materials due to their high content of dietary fiber, polyphenols, antioxidants, and bioactive compounds (Mirabella et al. 2014; Galanakis 2012). In accordance with circular economy principles, their valorization results in waste reduction, resource efficiency, and the development of sustainable food systems (Difonzo et al. 2023). The main categories of plant by-products include peels and skins, seeds, pomace (mixtures of peels, seeds, and pulp), pulp residues, and cereal fractions such as bran and husks. Among these, tomato processing by-products (peels, seeds, pomace) and carob by-products (pulp, flour, molasses residues) are of particular interest due to their high availability, abundant chemical composition, and functional potential (Difonzo et al. 2023; Özbek and Özdemir 2024).

Bioactive compounds occurring in plant by-products. Plant by-products possess a complex and valuable composition, including dietary fibers, polyphenols, polysaccharides, proteins, lipids, minerals, and natural pigments. The main and most abundant fraction is dietary fiber - both insoluble and soluble, mainly composed of cellulose, hemicellulose, lignin, and pectins (Galanakis 2012). Flavonoids and phenolic acids, as well as other phenolic compounds, are responsible for significant antioxidant activity and potential antimicrobial effects (Marchiani et al. 2016; Lucera et al. 2018). Many by-products contain natural pigments such as carotenoids and anthocyanins, as well as residual proteins and lipids, particularly in seed fractions (Marchiani et al. 2016). Some of these compounds also possess technological functionality, such as water-binding capacity. They influence textural characteristics and oxidative stability and can enhance the sensory note of the product (Difonzo et al. 2023; Galanakis 2012). These characteristics make by-products attractive ingredients for food fortification and functional product development.

Carob and tomato by-products. Tomato by-products are sourced from different tomato processing - juice, paste, sauces, and ketchup production. They generate large quantities of tomato peels, tomato seeds, and tomato pomace, the latter being a mixture of peels and seeds. These by-products are usually dried and finely milled before application in food systems (Solhi et al. 2020; Çakır et al. 2025). Similar to other plant by-products, their chemical composition is rich in insoluble dietary fiber, mainly cellulose and hemicellulose, which contributes to their high water-binding capacity (Çakır et al. 2025). The presence of dietary fiber may also exert prebiotic effects, supporting gut microbiota activity (Galanakis 2012). Significant amounts of polyphenolic compounds (flavonoids and phenolic acids) are found, which explain their high antioxidant activity (Lucera et al. 2018). This activity leads to improved oxidative stability of fats, particularly in dairy matrices (Solhi et al. 2020). The most remarkable compounds in their composition are carotenoids, especially lycopene, which explain their red color and strong antioxidant properties (Solhi et al. 2020). The natural red pigmentation must be taken into account when developing enriched products. The presence of unsaturated fatty acids enhances product's nutritional and biological value (Marchiani et al. 2016). The product enriched with tomato by-products generally demonstrates high water-holding capacity, leading to increased moisture retention and yield in food products (Çakır et al. 2025).

By-products obtained from the processing of carob (*Ceratonia siliqua* L.), such as carob pulp after removal of seeds, carob flour or powder from ground pods, and carob molasses pulp - the solid residue remaining after syrup extraction (Özbek et al. 2024; Difonzo et al. 2023) are characterized by a high content of soluble and insoluble dietary fiber (Özbek et al. 2024). The specific chemical composition of carob-based by-products makes them suitable texture modifiers and natural stabilizers with water-holding capacity in food systems (Özbek et al. 2024). Natural sugars (glucose, fructose, and sucrose) are also present in carob by-products, providing essential sweetness and contributing to the product's flavor profile (Difonzo et al. 2023). Additionally, carob by-products are a source of polyphenols and tannins with antioxidant properties (Galanakis 2012).

Like other plant residues, carob contains moderate levels of protein, low fat content, but is rich in minerals, particularly calcium and potassium (Difonzo et al. 2023; Özbek and Özdemir 2024). The functional and technological properties of carob residues are due to the above-mentioned composition. They possess texturizing properties and improve body and mouthfeel. They provide a specific sensory profile to the enriched product because of their natural sweetness and cocoa-like aroma, and can even replace sugars (Difonzo et al. 2023; Özbek and Özdemir 2024). Carob by-products also exhibit antioxidant activity, contributing to shelf-life extension and oxidative stability (Galanakis 2012). The successful incorporation of carob molasses pulp into spreadable and soft cheeses at levels up to 10–15% has been reported, resulting in increased moisture retention and acceptable sensory quality (Özbek and Özdemir 2024).

Dairy products enriched with plant waste extracts

Dairy products enriched with cereal by-products. The residues such as bran, husks, and fiber-rich fractions have been widely explored as functional ingredients in dairy products. These by-products are rich in dietary fiber, antioxidants, and bioactive compounds that improve water-holding capacity, texture, and nutritional value of dairy matrices.

Christaki et al. (2021) demonstrate, a plethora of advancements have been made and utilised for the industrial production of cheese. These advancements include the use of waste and by-products as a natural biosource of beneficial added-value compounds, such as proteins, lipids, carbohydrates, micronutrients, polyphenols, glucosinolates, carotenoids and dietary fibres. As posited by Torres-León et al. (2018), these compounds have the capacity to enhance nutritional value whilst concomitantly diminishing the environmental impacts of food waste and by-products. Research conducted on the utilisation of by-products in the context of cheese production has indicated that the primary objectives are twofold: firstly, to enhance the shelf life of cheeses through the antioxidant and antimicrobial activities of functional molecules, and secondly, to investigate the structural modifications and sensory

characteristics of novel cheese formulations (Difonzo et al. 2022).

It has been documented that waste and by-products from the dairy and cereal industries have the potential to enhance the storage quality and functional value of cheese. As Abd Elhamid (2016) discovered, the incorporation of wheat bran into traditional Egyptian cheese "Kariesh" (up to 0.4%) led to an increase in the fibre content of the cheese. However, this process also resulted in a significant decrease in the rheological properties of the cheese, including hardness, adhesiveness, springiness, cohesiveness, gumminess, chewiness, and resilience. Furthermore, cereal by-products, including wheat germ and oat bran, have been shown to enhance the sensory quality of soft cow's milk cheese (Tariq Khan and Ali Mosa, 2017). Other natural biosources, such as corn bran, have also been reported to enhance these activities.

Dairy products enriched with horticultural by-products. Horticultural residues derived from fruits and vegetables, including tomato pomace, grape pomace, olive leaves, pomegranate rind, broccoli, and artichoke by-products, have shown significant potential for dairy fortification. These materials are rich in polyphenols, carotenoids, and natural pigments that enhance antioxidant activity and improve shelf-life stability. Studies demonstrate that tomato-derived ingredients improve antioxidant capacity, increase phenolic content, and influence color and texture characteristics of yogurt and cheese. Similarly, grape pomace incorporation enhances aromatic complexity and bioactive properties, although high concentrations may affect sensory attributes such as astringency.

Antioxidant activity has been defined as the inhibition of nutrient oxidation. This activity can be carried out by various antioxidant compounds, which have been shown to prolong the shelf life of foods (Guclu et al. 2021). In the context of cheese production, the oxidation of lipids is a pivotal process that can result in the formation of hydroperoxides. These hydroperoxides, in turn, have the potential to contribute to the development of undesirable flavors within the final product. The phenomenon, characterised by the secretion of fatty acids and an escalation in microbial activity, culminates in the deterioration and unacceptability of the cheese. A plethora of antioxidant compounds, including polyphenols, tocopherols, and carotenoids, have been identified in the by-products of fruits and vegetables. These compounds have the capacity to impede oxidative processes and extend the shelf life of products (Agourram et al. 2013; Natalello et al. 2020; El-Dardiry 2021; Silva et al. 2022).

The antioxidant activity of a by-product added to a cheese formulation is contingent on the amounts of antioxidants present in the matrix. The quantities of these substances vary according to the starting matrix, and the antioxidant power can be influenced by intrinsic factors such as composition, geographical origin, and seasonal factors (Costa et al. 2018; Lucera et al. 2018; Frühbauerová et al. 2020; Gaglio et al. 2021; Barbaccia et al. 2022). Intrinsic factors also include types of treatments and various parameters that can change the effectiveness of the by-product (Difonzo et al. 2022).

Frühbauerová et al. (2020) demonstrated the impact of grape peel treatment on the polyphenol content of a spreadable cheese product fortified with grape peel extract. The application of a freeze-drying treatment resulted in a higher concentration of polyphenols than the conventional drying method (0.13 mg GAE.100 g^{-1} dry matter (DM) for the control sample to 0.47 mg GAE/100 g DM for cheese with oven-dried and freeze-dried grape skin powder, respectively, as identified via Folin–Ciocalteau assay). Furthermore, distillation of Chardonnay grape pomace extract was demonstrated to enhance the polyphenol content within the matrix. As Marchiani et al. (2016) observed, the supplementation of semi-hard cheeses, comparable to Italian Toma, with grape pomace powders (Barbera and Chardonnay) at a concentration of 1.6% (w/w) resulted in a substantial enhancement of phenolic content, radical scavenging activity and antioxidant activity. This assertion is corroborated by the findings of Marchiani et al. (2016), who demonstrated that the addition of distilled Chardonnay grape pomace extract to the manufacturing process resulted in a higher total polyphenol content in Toma and Cheddar cheeses compared to the use of an undistilled extract. Lucera et al. (2018) discovered that cheese fortified with grape pomace powder demonstrated a considerably elevated increase in total phenolic content, flavonoids, and antioxidant activity in comparison to the control cheese. It has

been demonstrated that other natural biosources, including broccoli, artichokes, and tomato peel, have the capacity to increase these activities. The validity of these results was confirmed by Gaglio et al. (2021), who utilised grape pomace powder to fortify fresh ovine "primosale" cheese. The cheese was produced using pasteurized ewes' milk and enriched with 1% (w/w) of grape pomace powder and selected *Lactococcus lactis* strains resistant to the main grape polyphenols. The findings demonstrated that fortification led to a reduction in fat content, accompanied by an increase in protein and secondary lipid peroxidation. Furthermore, the in vitro simulation of human digestion revealed a substantial enhancement in antioxidant capacity, as measured by radical scavenging activity, and the inhibition of membrane lipid peroxidation. Italian Vastedda cheese, fortified with 1% (w/w) of red grape pomace powder and produced using four lactic acid bacteria and ovine milk, demonstrated a decline in fat content, an increase in protein content, and higher values of secondary lipid oxidation. As demonstrated in the research by Khalil et al. (2019), Sandhya et al. (2019), Cangussu et al. (2021), Parafati et al. (2021) and Mushtaq et al. (2018) the extracts obtained from pomegranate skin and mesocarp have been shown to produce an increase in antioxidant activity when added to the formulations of buffalo and cow cheeses. In the study by Khalil et al. (2019), 0.25 or 0.50 $g.kg^{-1}$ of hydroalcoholic pomegranate peel extract was added to buffalo feta cheese. The phenolic acids that were identified in high concentrations in the pomegranate peel extract were ellagic, gallic, and caffeic acids (36.24, 124, and 24.68 $mg.100\ g^{-1}$ of dried extract, respectively). The resultant cheese demonstrated enhanced oxidative stability. In another study (Mahajan et al. 2015), Kalari cheese was immersed in an aqueous solution containing 1 and 2% pomegranate peel extract. In this case, the antioxidant activity of the ellagic acid contained in the extract limited the lipid oxidation of the cheese over 28 days of storage. Following a storage period of 28 days at 4°C, Mahajan et al. (2015) demonstrated that the utilisation of pomegranate rind extract (2000 $mg.100\ mL^{-1}$) as a natural preservative in buffalo cheese "Kalari" resulted in a reduction of thiobarbituric acid reacting substances (15%) and a decline in free fatty acid content (24%) in comparison to the control group.

In the study by Parafati et al. (2021), 0.05% (w/v) of pomegranate peel and mesocarp aqueous extract was added to cow's milk prior to the coagulation process. The analysis demonstrated that the cheese containing pomegranate peel extract exhibited a higher level of total polyphenols in comparison to the cheese containing pomegranate mesocarp extract. The polyphenols present in higher amounts were identified as ellagic acid, punicalagin isomer, and gallagyl-hexoside (6.67, 10.24, and 8.43 $mg.g^{-1}$ of fresh vegetable material), which exhibited antioxidant activity when added to a cheese formulation in the form of peel extract. A separate investigation by Mushtaq et al. (2018) involved the fabrication of a biofilm with pomegranate peel aqueous extract for the purpose of enveloping Himalayan cheese. The findings demonstrated a decline in lipid and protein oxidation in cheeses that had been coated with a film fortified with pomegranate peel extract. The antioxidant activity was enhanced with increasing concentration of the extract in the film. This finding is of particular significance in view of the fact that it significantly limited the oxidation of the cheese during the 30-day storage period.

Incorporating lemon and mandarin peel extract to curtail oxidation in buffalo feta, buffalo labneh, and processed cow's milk cheese, respectively. The molecules responsible for the antioxidant effects observed in the study were identified as ferulic acid and coumaric acid in lemon peel extract, and gallic acid, catechins, coumaric acids, and rutin in mandarin peel extract, as determined by HPLC analysis (El-Messery et al. 2019; Khalil et al. 2019; Ebid and Mabrour 2022).

Posseti et al. (2020) undertook a research study on the polyphenol content of three different varieties of Brazilian mango. The functional properties of mango kernels have been demonstrated through their capacity to enhance the shelf life of Minas Frescal cheese. In a separate study, Khan et al. (2018) demonstrated the presence of chlorogenic acid, caffeic acid, catechin, quercetin, and mangiferin in mango kernel extract when incorporated into the formulation of Gouda cheese, thereby enhancing its antioxidant properties. In this context, the research of Serna-Cock et al. (2016) has focused on the utilisation of dried powdered mango peel for the development of cheese as a source of dietary fibre and to enhance antioxidant activity.

Furthermore, the utilisation of mango skin or kernel as a fat substitute in cheese production has been demonstrated. The replacement of a proportion of the fat in Gouda cheese with mango kernel has been demonstrated to enhance sensory characteristics, total phenolic contents, 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical scavenging activity, total flavonoids, and concentrations of *trans* fatty acids (e.g., C18:1, C18:2, and C18:3). In addition, the fortification of cheese with mango kernels has been shown to result in the presence of added-value compounds, including mangiferin, caffeic acid, catechin, quercetin, and chlorogenic acid (Khan et al. 2018).

Lucera et al. (2018) and Costa et al. (2018) established the hypothesis that the incorporation of wine by-products in the manufacturing process of cheese results in alterations to the texture of the final product. The addition of pomace to the cheese-making process resulted in a lower pH value, which in turn led to a reduction in syneresis (Costa et al. 2018; Lucera et al. 2018).

Consequently, the by-product may have a reduced impact on sensory properties, thus encouraging the utilisation of these fortifiers in the production of cheese (Costa et al. 2018; Lucera et al. 2018; Barbaccia et al. 2022; Gaglio et al. 2021; Kandylis et al. 2021). The addition of other by-products, such as tomato peel and celery leaves, to a cheese formulation, has been shown to enhance its acceptability (Awda et al. 2019; Zayan et al. 2021). However, in certain instances, the product's acceptability was found to be inferior to that of the conventional cheese, as evidenced by the study on the incorporation of mandarin peel extract into processed cow's milk cheese (El-Messery et al. 2019).

Lucera et al. (2018) reported that the incorporation of flour developed from artichoke external leaves at a concentration of 5% (w/w) led to an increase in the total phenolic content of cheeses produced from pasteurised skimmed cow's milk (0.1% fat) from 0.66 to 1.20 mg GAEs.g^{-1} in dry weight. However, this addition also resulted in a perception of bitterness.

It has been demonstrated that strawberry by-products contain ellagic acid and phenolic antioxidants, which have the potential to be utilised in the preservation of cheese (Ariza et al. 2018). Conversely, a combination of liquid chromatography with tandem mass spectrometry (LC-MS) was employed to examine a sample of *Arbutus unedo* L., yielding insights into the predominant phenolic compounds present, identified as quinic acid and catechin at a concentration of 0.3 g.L^{-1}. These phenolic compounds were found to possess antioxidant characteristics in a modified soft cheese matrix (Masmoudi et al. 2020).

Roila et al. (2019) conducted an investigation into the utilisation of a polyphenolic extract derived from olive oil by-products, with a view to enhancing the storage stability of "Fior di latte" cheese during the storage period. The extract was added to two batches of cheese at concentrations of 250 and 500 µg.mL^{-1}. The results demonstrated that the extract inhibited the growth of *P. fluorescens* and *Enterobacteriaceae*, thereby delaying the attainment of the microbial limit. Consequently, the shelf life of the cheese was extended by 2 and 4 days, respectively, for the two applied concentrations. The incorporation of the extract resulted in a substantial augmentation of the total phenolic content of the cheese, thereby enhancing its functional value and health-promoting properties.

In a study conducted by Mileriene et al. (2021), liquid whey protein, a by-product of the common dairy industry, was utilised in the formulation of an edible coating. This coating was enhanced with 0.3% Chinese cinnamon extract, with the aim of prolonging the shelf life of Eastern European curd cheese. The application of the coating resulted in a reduction in yeast and fungal populations, whilst concomitantly enhancing the aesthetic quality of the cheese. These alterations did not, however, affect its sensory characteristics. The utilisation of food waste and by-products powder and extract has been demonstrated to enhance the shelf life of products, augment their nutritional value (as evidenced by an increase in total flavonoids and phenolic compounds, a reduction in fat content, and an enhancement in fibre levels), while ensuring that safety objectives, sensory attributes, and consumer acceptance remain intact (Baker et al. 2022; Picciotti et al. 2022). The summarized findings could be presented in Table 1.

Table 1. Dairy products enriched with bioactive compounds from plant by-products

Product	Bioactive compound	Quantity	Effect	Source
Yoghurt	Aromatic plant extracts of *Satureja hortensis* L. and *Rosmarinus officinalis* L.	0.15, 0.30, 0.45 and 0.60%	Increased yoghurt shelf-life	(Popescu et al. 2023a)
Yogurt	Red grape skin powder	0.5%, 1.0%, and 1.5%	Increased the total phenolic content and improved nutritional value	(Covaliov et al. 2024)
Yoghurt	Apple pomace powder	0.2 0.4, 0.6, 0.8 and 1%	Enhanced sensory and textural parameters	(Popescu et al. 2022)
Cream cheese	Basil extract	0.3%, 0.6%, 0.9%, 1.2%	Inhibition of the post-fermentation process, improvement in the degree of water retention and textural parameters	(Popescu et al. 2023b)
Buffalo Feta Cheese	Pomegranate peel hydroalcoholic extract	0.25–0.50 $g.kg^{-1}$	Increased antioxidant activity, enhanced oxidative stability	(Khalil et al. 2019)
Kalari Cheese (Buffalo)	Pomegranate peel extract	1–2% (aqueous) / 2000 $mg.100\ mL^{-1}$	Reduced lipid oxidation (↓TBARS 15%, ↓FFA 24%), prolonged shelf life	(Mahajan et al. 2015)
Cow Cheese	Pomegranate peel/mesocarp aqueous extract	0.05% (w/v)	Higher total polyphenols, antioxidant activity	(Parafati et al. 2021)
Himalayan Cheese	Pomegranate peel aqueous extract (biofilm coating)	Not specified	Reduced lipid & protein oxidation during 30-day storage	(Mushtaq et al. 2018)
Buffalo Feta, Buffalo Labneh, Processed Cow Cheese	Lemon peel extract / Mandarin peel extract	Not specified	Antioxidant activity, reduced lipid oxidation	(Khalil et al. 2019; El-Messery et al. 2019; Ebid and Mabrour 2022)
Spreadable Cheese	Grape peel extract (oven-dried/freeze-dried)	0.13–0.47 mg GAE.100 g^{-1} DM	Increased polyphenol content and antioxidant activity	(Frühbauerová et al. 2020)
Semi-hard Cheese (Toma, Cheddar)	Grape pomace powder / distilled Chardonnay pomace extract	1.6% (w/w)	Increased polyphenol content, radical scavenging activity, antioxidant activity	(Marchiani et al. 2016)

Italian Vastedda Cheese	Red grape pomace powder	1% (w/w)	Reduced fat, increased protein, higher secondary lipid oxidation	(Lucera et al. 2018)
Gouda Cheese	Mango kernel and mango peel extract	Not specified	Increased total phenolics, flavonoids, DPPH activity; improved sensory characteristics; Source of dietary fiber, enhanced antioxidant activity	(Khan et al. 2018; Serna-Cock 2016)
Spreadable Cheese	Red and white grape pomace	Not specified	Enhanced aromatic complexity, marbled aspect	(Costa et al. 2018; Lucera et al. 2018)
Soft Cow's Milk Cheese	Wheat germ, oat bran	0-2%	Improved sensory quality	(Tariq Khan and Ali Mosa, 2017)
Processed Cow's Milk Cheese	Mandarin peel extract	Not specified	Sensory acceptability may be lower than conventional	(El-Messery et al. 2019)
Cow's Milk Cheese	Artichoke external leaves flour	5% (w/w)	Increased total phenolic content, slight bitterness	(Lucera et al., 2018)
Soft Cheese	Strawberry by-products	Not specified	Enhanced antioxidant activity	(Ariza et al. 2018)
Soft Cheese (*Arbutus unedo* L.)	Quinic acid, catechin	0.3 $g.L^{-1}$	Enhanced antioxidant activity	(Masmoudi et al. 2020)
Fior di Latte Cheese	Olive oil polyphenolic extract	250–500 $\mu g.mL^{-1}$	Extended shelf life by 2–4 days, inhibited *P. fluorescens* and *Enterobacteriaceae*	(Roila et al. 2019)
Kariesh Cheese (Egyptian)	Wheat bran	Up to 0.4%	Increased fiber content, reduced rheological properties	(Abd Elhamid, 2016)
Eastern European Curd Cheese	Whey protein coating + 0.3% Chinese cinnamon extract	0.3%	Reduced yeast and fungi, enhanced aesthetic quality, maintained sensory properties	(Mileriene et al. 2021)

GAE - Gallic Acid Equivalents; DM - Dry Matter; DPPH - 2,2-diphenyl-1-picrylhydrazyl;

Microbiological characteristics of dairy products enriched with bioactive compounds from plant by-products. Several studies demonstrate the influence of a biologically active ingredient derived from a plant waste product on the finished product's quality characteristics. The use of by-product substances has been shown to limit microbial proliferation notably that of pathogenic microorganisms, without compromising the functional activities of starter cultures and other beneficial microorganisms in the cheesemaking process (Moreira et al. 2019).

The use of pomegranate peel is a well-documented practice, attributed to its capacity to impede the proliferation of yeasts, molds, and undesirable bacterial strains. To enhance microbial stability and prolong the shelf life of cheese, Mahajan et al. (2015) incorporated 1% and 2% pomegranate extract into low-fat Kalari.

In a separate study, Parafati et al. (2021) added 0.05% (w/v) pomegranate peel to the cheese matrix. The incorporation of pomegranate peel is attributed to its capacity to inhibit the growth of undesirable microorganisms, such as yeasts, molds, and bacteria. The findings of the two studies demonstrated a decline in the prevalence of various bacterial species, including *Escherichia coli*, *Pseudomonas perfringens*, *Micrococcus luteus*, *Enterococci faecalis*, *Staphylococcus aureus*, *Proteus vulgaris*, *Salmonella typhii*, *Staphylococcus hemolyticus*, *Pseudomonas fluorescens*, *Bacillus subtilis*, and *Bacillus cereus*.

As demonstrated by Mushtaq et al. (2018), phenolic compounds extracted from pomegranate peel have been shown to exert a bactericidal effect against undesirable microorganisms. This allows probiotic lactic bacteria to proliferate more easily during the preservation of buffalo Kalari cheese.

In addition, lycopene extracted from tomato by-products has been shown to protect milk derivatives from spoilage (Kaur et al. 2011). The protective properties exhibited by these samples were attributed to the presence of value-added molecules derived from agri-food waste. Following a storage period of 28 days at 4°C, Mahajan et al. (2015) demonstrated that the utilization of pomegranate rind extract (2000 mg.100 mL^{-1}) as a natural preservative in buffalo cheese "Kalari" resulted in a 15% reduction in thiobarbituric acid-reacting substances and a 24% decline in free fatty acid content compared with the control group. The effect was also found to be dose-dependent; increasing the extract dosage from 25 to 75 mg resulted in an increase of approximately 5 mm in the zone of inhibition of antimicrobial activity for *Escherichia coli*, and 10–12 mm for *Proteus vulgaris*, *Pseudomonas aeruginosa*, *Micrococcus luteus*, *Enterococcus faecalis*, *Staphylococcus aureus*, and *Salmonella typhi*. The addition of mango peel and kernel extracts to soft cow's milk cheese has been shown to possess bacteriostatic properties against coliform cells. In this study by Posseti et al. (2020), the presence of 6% extract in the cheese sample demonstrated favourable resistance to microbial growth during storage. The study observed limited growth of coagulase-positive *Staphylococcus*, and *Salmonella* and *Listeria monocytogenes* were confirmed absent.

Banana peel pectin aqueous extract, when used as an edible coating for fresh mozzarella cheese, also demonstrated antibacterial activity against *Escherichia coli*, *Staphylococcus aureus*, and *Salmonella enteritidis*.

Terpou et al. (2018) extended the shelf life of buffalo mozzarella from 7 to 21 days by applying an edible coating composed of 3 mg of banana peel pectin extract. The coating significantly improved the microbial quality of the mozzarella, with no yeast, mold, or coliform growth observed up to 21 days of storage. This result contrasts with uncoated mozzarella, which exhibited 2.3×10^2 $CFU.mg^{-1}$ as early as the seventh day of storage. The limited growth of spoilage microorganisms has extended the shelf life of coated mozzarella cheeses from 7 to 21 days (Tripath and Mishra 2021). The assessment of the microbiological influence of biologically active ingredients can be systematized as shown in Fig. 2.

Dairy products enriched with tomato and carob by-products. In recent years, there has been growing interest in the sustainable valorization of plant-based food industry by-products by incorporating them into various dairy products. This approach aims to enhance the functional properties, technological performance, and health benefits of the final products (Kandyliari et al. 2023; Sendra et al. 2010; Tseng and Zhao 2013; Marchiani et al. 2016; Vital et al. 2015).

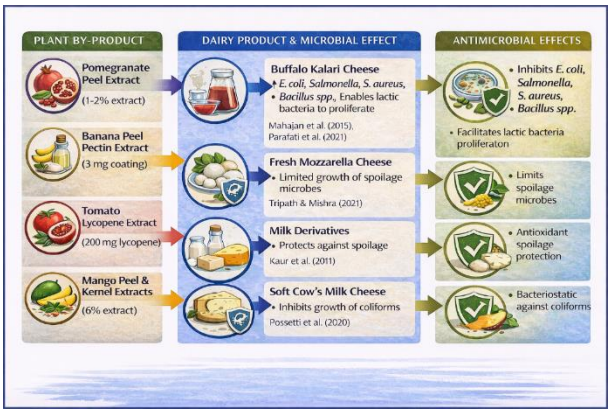


Figure 2. Influence of biologically active compounds from plant by-products on the microbiological characteristics of dairy products (Figure created using the authors' original text with visualization support from ChatGPT (OpenAI))

The increasing interest in incorporating tomato by-products into dairy matrices is driven by their high content of bioactive compounds, including lycopene, phenolic compounds, and dietary fibers (Shi 2000; Sharma and Maguer 1996; Rizk et al. 2014). At present, particular attention is being paid to the sustainable utilization of tomato processing by-products, including tomato peels, skins, whole tomato powder, and phenolic and carotenoid extracts. The summarized results from the literature sources are presented in Table 2.

In summary, available studies show that tomato by-products and their derivatives can be successfully incorporated into yogurt across a wide concentration range (0.5–8%). Lower inclusion levels (0.5–2%) generally offer the best balance among technological, functional, and sensory properties. The observed differences in effects are primarily attributable to the form of the tomato raw material (pomace, tomato peels, whole tomato powder) and its chemical composition, rather than to intrinsic limitations of the dairy matrix. This confirms that the potential to incorporate tomato by-products into functional dairy products remains underexploited and represents a promising direction for future research.

Lycopene is the main carotenoid pigment in tomatoes and is responsible for their antioxidant activity. It has been found that the lycopene content in tomato peels and scales is significantly higher than in tomato pulp, making them suitable as natural colorants and functional ingredients in dairy products (Sharma and Maguer 1996). Rizk et al. (2014) reported that carotenoids extracted from tomato peels can be used as natural colorants in ice cream and can significantly increase its antioxidant activity. The conducted studies support the concept that tomato extracts retain their functional properties and color stability in the dairy system, including during heat treatment and freezing.

Particular attention has been given to tomato by-products because of their high content of bioactive compounds. Lycopene is the primary carotenoid pigment responsible for the characteristic red color of tomatoes (Shi 2000). Tomato peels contain approximately five times more lycopene than whole tomato pulp (Sharma and Maguer 1996), which explains the pronounced color and antioxidant potential of tomato pomace and skins, as well as their suitability for incorporation into functional dairy products.

Lycopene has practical applications in the food industry as a natural colorant, and Rizk et al. (2014) reported that it imparted stable color and antioxidant properties when added to ice cream base. On the other hand, several authors emphasize that the direct inclusion of tomato powder or tomato pulp in dairy products is a more practical and economically advantageous approach than isolated lycopene, since the synergistic action between carotenoids, polyphenols, and dietary fiber is preserved (Jefrin et al. 2022).

Therefore, various studies have been conducted on the influence of tomato powder or pulp on the techno-functional characteristics of fermented dairy products and their sensory perception. In fermented milks, a dual effect is most often reported, depending on the type and dose of the added ingredient: an increase in bioactive potential (phenolic content and antioxidant activity) and changes in textural characteristics, including water retention capacity. Alqahtani et al. (2020) investigated the effects of adding tomato pomace at concentrations of 0.5, 1.0, 1.5, and 2.0% in the production of set-type yogurt on antioxidant activity, pH, and syneresis during 14 days of refrigerated storage at 4°C. The authors found that increasing the added concentration led to a significant increase in the antioxidant profile, a significant increase in the antioxidant profile, a decrease in pH, and syneresis.

Table 2. Dairy products enriched with bioactive compounds from tomato and carob by-products

Product	Bioactive compound	Quantity	Effect	Source
Yogurt (set-style)	Tomato pomace (lycopene, phenolics, dietary fiber)	0.5–2.0%	Increased antioxidant activity and total phenolic content, reduced pH and syneresis, improved viscosity and texture, good LAB viability	(Alqahtani et al. 2020)
Yogurt	Whole tomato powder	2–4%	No adverse effect on fermentation, maintained LAB viability, increased L. delbrueckii counts	(Grillia and Naziri 2026)
Yogurt (probiotic)	Tomato powder (hot-break, cold-break)	0.5–2.0%	Increased antioxidant activity, maintained water-holding capacity, probiotic viability >10^6 CFU.g^{-1}, slight reduction in firmness	(Demirci et al. 2020)
Yogurt	Freeze-dried tomato peel powder	0.1 and 0.2 %	Best sensory acceptance at 0.1%	(Jefrin et al. 2022)
Ice cream	Carotenoids extracted from tomato peels (lycopene)	Not specified	Improved color characteristics and significantly increased antioxidant activity	(Rizk et al. 2014)
Fresh, processed and semi-hard cheeses (e.g. kashkaval)	Tomato by-products (pomace, powder)	Controlled levels	Improved color, antioxidant potential, and acceptable sensory properties	(Solhi et al. 2020; Torri et al. 2016)
Processed cheese	Lycopene extracted from tomato waste (in palm oil)	25.4% palm oil containing lycopene	Increased lycopene, iron, phenolics, antioxidant activity; increased meltability, reduced oil separation; improved sensory scores	(Hassan et al. 2019)

Processed cheese	Tomato powder (lycopene, phenolics)	1%, 2%, 4% (w/w)	Increased phenolics, lycopene, and antioxidants activity; reduced pH and lipolysis; decreased rigidity; increased spreadability; 2% optimal sensory acceptance	(Solhi et al. 2020)
Primosale cheese	Tomato peel, broccoli, artichoke, grape pomace flours	50 and 100 $g \cdot kg^{-1}$	Improved nutritional profile, increased friability and adhesiveness, enhanced sensory attributes	(Costa et al. 2018)
Yogurt	Carob pulp flour	1.0–1.5%	No significant change in titratable acidity, improved structure	(Elmehrach et al. 2019)
Yogurt	Whole carob pod powder	≥2%	Increased acidity, enhanced LAB activity	(Elmehrach et al. 2019)
Yogurt (probiotic)	Carob extract	Not specified	Improved survival of *L. acidophilus* and Bifidobacterium BB-12	(Güler-Akin et al. 2016)
Yogurt	Carob pulp flour + starch	1.5% carob + 1.0–1.5% starch	Improved viscosity and consistency (synergistic stabilizing effect)	(Elmehrach et al. 2019)
Yogurt (camel milk, lactose-free)	Carob (fiber, polyphenols)	Not specified	Improved rheological properties and water-holding capacity	(Froiio et al. 2020)
Yogurt (probiotic)	Carob pulp (fiber, sugars, polyphenols)	Not specified	Enhanced early probiotic survival, increased antioxidant activity (DPPH, iron chelation)	(Arab et al. 2022)

In addition, viscosity and textural properties improved significantly. At the end of storage, the viability of *L. delbrueckii* subsp. *bulgaricus* remained approximately 6.3–6.7 log CFU.g^{-1} and over 8.5 log CFU.g^{-1} for *S. thermophilus*. This indicates good compatibility of tomato pomace with lactic acid bacteria and suggests a potential prebiotic effect from its fiber fraction. Polysaccharides in tomato powder, particularly pectin, act as hydrocolloids, binding water molecules and forming associative interactions with milk proteins. These interactions limit the mobility of water molecules, thereby improving the water-holding capacity of the coagulum and densifying the casein network (Saffolo et al. 2024).

In contrast, Grillia and Naziri (2026) used whole tomato powder, classified as food waste, at concentrations of 2% and 4%, emphasizing sustainable raw material use. Despite the additive's distinct chemical profile – higher soluble solids and pigments, lower structural fiber, the authors observed no adverse effects on fermentation or product stability. The yogurts maintained lactic acid bacteria viability within the typical range for fermented dairy products (10^6–10^7 CFU.g^{-1}), while tomato-enriched samples showed higher initial levels of *L. delbrueckii* subsp. *bulgaricus*, likely due to fermentable sugars and trace elements in the tomato powder.

Demirci et al. (2020) reported similar results, investigating tomato powders produced by hot-break and cold-break technologies and incorporated into yogurts at 0.5, 1.0, and 2% concentrations, with the probiotic strain *Lactobacillus paracasei* F19. The highest antioxidant activity was observed at 2% hot-break tomato powder, with DPPH and ABTS$^+$ radical-scavenging values significantly exceeding those of control samples. Although the addition of tomato powders reduced firmness and consistency, water-holding capacity was not adversely affected, and probiotic viability remained above 10^6 CFU.g^{-1} after 21 days of storage. In particular, polysaccharides in tomato powder, particularly pectin, function as hydrocolloid stabilizers by binding water molecules and forming associative interactions with milk proteins, thereby limiting water mobility, improving gel hydration, and strengthening the casein network (Saffolo et al. 2024). Consequently, the increased water-holding capacity of tomato-enriched yogurts can be attributed to the high dietary fiber content of tomato powder, particularly pectin, which interacts with milk proteins and enhances the ability of the gel structure to retain water (Gyawali and Ibrahim 2018; Lelal et al. 2024).

The data reported by Jefrin et al. (2022) further complement these findings, showing that incorporating freeze-dried tomato peel powder at higher concentrations (up to 8%) yields the highest antioxidant activity and the most intense product coloration. However, lower inclusion levels (approximately 2%) were rated as most acceptable by consumers, underscoring the need to optimize concentration to balance functional benefits with sensory acceptability.

The observed color changes in tomato-enriched yogurts are directly related to the chemical composition of the tomato ingredients used. The primary drivers of the decrease in the L* parameter (darkening) and the increases in a* and b* values are high carotenoid content, particularly lycopene. Lycopene imparts intense red–orange hues that dominate the dairy matrix's natural white color, shifting the overall color balance toward warmer tones. The intensity of these changes is concentration-dependent and influenced by both the amount of tomato ingredient added and its form and technological processing. Products containing whole tomato powder generally exhibit more pronounced coloration than those enriched with tomato pomace, due to higher pigment content and better pigment dispersion.

Concurrently, the hardness of Primosale cheese fortified with tomato, broccoli, and artichoke by-products increased (Costa et al. 2018). Sensory analysis indicated that adding red and white grape pomace to spreadable and Primosale cheeses produced a marbled appearance, along with astringency, fibrousness, friability, acidity, salinity, and adhesiveness. The use of pomace notably enhanced the product's aromatic complexity. Furthermore, it has been hypothesized that certain sensory attributes, including earthy, vinous, and those associated with the addition of powder, may have been constrained by enhanced dispersion within the cheese matrix (Costa et al. 2018; Lucera et al. 2018). Successful application of tomato by-products has been reported in fresh cheeses, processed cheeses, and, at controlled levels, in semi-

hard cheeses such as kashkaval (Solhi et al. 2020; Torri et al. 2016).

In a study by Hassan et al. (2019), lycopene was extracted from tomato waste to incorporate into a novel healthy processed cheese. Lycopene was extracted from tomato waste using palm oil and stored at 5℃ in a refrigerator until use. Two formulae of processed cheese were prepared for the experiment: the first served as the control sample (without lycopene), while the second served as the treated sample (fortified with 25.4% palm oil containing lycopene). The resultant cheese samples were stored for 3 months at 5 and 25℃. The findings of the study demonstrated that the samples subjected to the treatment exhibited higher concentrations of lycopene, iron, phenolic compounds, and antioxidant activity. Concurrently, the samples exhibited greater meltability and less oil separation than the control samples. The organoleptic properties indicated that the treated samples obtained higher scores than the control samples. In conclusion, lycopene can be used in the production of processed cheese, which is characterized by elevated concentrations of iron, antioxidants, and phenolic compounds.

In the study by Solhi et al. (2020), the rheological, chemical, and sensory characteristics of processed cheese containing varying amounts of tomato powder (0%, 1%, 2%, and 4% w/w) and bioactive components at appropriate levels were evaluated over a 90-day storage period. The results showed that the samples containing tomato powder exhibited higher levels of proteolysis extent, phenolic and lycopene contents, and antioxidant activity. However, they exhibited lower levels of pH and lipolysis indexes. In general, lycopene and phenolic contents and antioxidant activity decreased, while pH, proteolysis, and lipolysis index increased during storage. The findings of the study demonstrated that the samples exhibited a solid-type structure, and the presence of tomato powder resulted in a reduction in solid-like behavior. The sensory analysis demonstrated that the processed cheese with an average level of tomato powder (2%) exhibited optimal scores for flavor, color, and overall acceptance. Furthermore, a significant reduction in rigidity and increased spreadability were observed when compared to the control.

In the study by Zayan et al. (2021), the effects of replacing a proportion of butter with lycopene oil at 25%, 50%, and 75% were examined. Substituting butter with lycopene oil increased dry matter, ash, lycopene content, antioxidant activity, meltability, and sensory characteristics of processed cheese. As the level of incorporated lycopene oil increased, firmness decreased accordingly. The present study demonstrates that substituting butter with lycopene oil, obtained by means of a green extraction technique from tomato peel waste, in processed cheese can be used as a process for decreasing saturated fats in dairy products while maintaining the other desired characteristics of the product.

As Bendini et al. (2015), Ranveer and Sahoo (2014), Zourro et al. (2013), Kaur et al. (2011), and Rizk et al. (2014) demonstrate, the extraction of the lycopene pigment from peels is primarily carried out, and the pigment is subsequently reincorporated into a variety of foodstuffs. The utilization of tomato by-products as food ingredients has been predominantly associated with two primary applications. First, tomato by-products have been employed as a partial replacement for wheat flour in the production of baked goods (Mehta et al. 2018). Second, they have been incorporated into meat products (Savadkoohi et al. 2014). Moreover, tomato by-products have been utilized as a raw material in the production of ketchup (Belović et al. 2018) and as a flour for Primosale cheese (Costa et al. 2018).

In the study by Costa et al. (2018), the effects of two concentrations (50 and 100 g. kg^{-1}) of flours derived from diverse by-products (i.e., red and white wine grape pomace; tomato peel, broccoli, and artichokes) were examined as a potential source of dietary fiber and bioactive compounds. The study evaluated the swelling and water retention capacity of the flours, as well as the physicochemical characteristics of the cheese, bioactive compounds, and the sensory profile. The results showed that incorporating by-products into Primosale cheese enhanced its nutritional profile and certain sensory characteristics, including friability and adhesiveness. Among the products tested, Primosale cheese with artichoke by-products produced the most favorable result. Kandyliari et al. (2023) hypothesize that incorporating vegetable by-products into dairy products can enhance their nutritional profile, thereby reducing the prevalence

of a variety of diseases. This integration can also improve technological parameters, including yield by weight and the firmness of cheese products.

Carob (*Ceratonia siliqua* L.) has also emerged as a multifunctional plant-based ingredient with strong potential for use in fermented dairy products, owing to its favorable chemical composition, including dietary fiber, polyphenols, and natural sugars, as well as the absence of gluten, caffeine, and other methylxanthines (Froiio et al. 2020; Ikram et al. 2023). Compared with other plant-based sweeteners, such as dates, carob has lower sugar and higher protein content, making it suitable for developing functional dairy products for health-conscious consumers (Buzzanca et al. 2024). Carob flour could have health-promoting properties (Ruseva et al. 2024).

Available research indicates that the effects of carob in yogurt systems depend strongly on both the form of the ingredient used (pulp, whole pod, extract) and the level of incorporation. Elmehrach et al. (2019) demonstrated that adding carob pulp flour at 1.0–1.5% does not significantly alter titratable acidity compared with control samples, whereas whole carob pod powder significantly increases acidity. This effect is attributed to the higher content of fermentable sugars and bioactive compounds in the whole pod, which stimulates the metabolic activity of lactic acid bacteria. Similar conclusions were reported by Güler-Akin et al. (2016), who observed improved survival of *Lactobacillus acidophilus* and *Bifidobacterium animalis subsp. lactis BB-12* after supplementation with carob extract, likely due to its prebiotic and antioxidant properties.

The concentration-dependent rise in titratable acidity at higher carob inclusion levels (≥2%) aligns with the chemical composition of carob pods, which contain 48–56% carbohydrates, with sucrose comprising more than 30%, along with glucose and fructose (Gobindram et al. 2015). These readily fermentable sugars enhance lactic acid fermentation, resulting in more pronounced post-acidification during storage, an effect also reported by Arab et al. (2022).

From a technological perspective, dietary fiber in carob pulp plays a key role in stabilizing yogurt structure. Elmehrach et al. (2019) showed that combining 1.5% carob flour with 1.0–1.5% starch results in viscosity and consistency comparable to control samples, indicating a synergistic stabilizing effect. This observation aligns with findings by Froiio et al. (2020), who reported improved rheological properties and water-holding capacity in dairy systems enriched with carob, including camel milk and lactose-free products.

Microbiological results from multiple studies are complementary and reveal a dual effect of carob on probiotic viability. During early storage, dietary fiber and sugars in carob serve as substrates for probiotic microorganisms, explaining the enhanced survival of *Bifidobacterium animalis* subsp. *lactis* BB-12 reported by Arab et al. (2022). During prolonged storage, however, phenolic compounds and condensed tannins in carob pulp may exert moderate antimicrobial activity, leading to a gradual reduction in microbial counts without compromising the minimum recommended probiotic levels. This interpretation is supported by the chemical profile of carob, which contains 16–20% condensed tannins (Karababa and Coskunder 2013).

The functional advantages of carob are further enhanced by its significant antioxidant potential. The increased DPPH radical-scavenging and iron-chelating activities reported in carob-enriched yogurts (Arab et al. 2022) align with the high polyphenol and D-pinitol content of carob pods (Brassesco 2021). This allows functional enrichment to be achieved even at moderate inclusion levels while maintaining good sensory acceptability.

Conclusions

The valorization of plant-derived agro-food by-products represents a promising strategy for developing functional dairy products while simultaneously addressing environmental and economic challenges associated with food waste. This review demonstrates that plant by-products, particularly those derived from tomato, carob, cereals, and horticultural residues, are rich sources of dietary fiber, polyphenols, carotenoids, and other bioactive compounds that significantly enhance the nutritional, technological, and sensory properties of dairy products. Their incorporation into dairy matrices improves antioxidant activity, water-holding capacity, texture, microbial stability, and shelf-life characteristics, while supporting circular

economy principles through waste reduction and resource efficiency.

The use of plant by-products as sources of biologically active compounds has emerged as a current and promising research direction, with numerous studies reporting the application of various plant materials and extracts in functional dairy products due to their high biological value. However, the potential utilisation of agro-food residues originating from productions typical of the Balkan Peninsula, including tomato and carob processing by-products, remains largely underexplored. Furthermore, their incorporation into traditional Bulgarian dairy products, such as fermented milk, white brine cheese, and Kashkaval cheese, has received limited scientific attention.

Despite their demonstrated functional potential, several challenges remain, including variability in raw material composition, standardization of processing methods, optimization of incorporation levels, regulatory considerations, and maintenance of consumer acceptability. This review provides a comprehensive synthesis of current knowledge on the application of plant agro-food by-products in dairy systems, highlighting their technological benefits while identifying key industrial limitations.

Future research should focus on process optimization, safety assessment, consumer perception studies, and large-scale implementation strategies, particularly targeting plant-derived secondary products prevalent in specific regions. The integration of these by-products into dairy production represents a sustainable pathway toward functional food innovation, enhanced nutritional quality of fresh and matured dairy products, and the development of a circular bioeconomy.

Acknowledgements

The authors acknowledge financial support from Project BG16RFPR002-1.014-0012-C01 "Establishment and Sustainable Development of a Center of Competence 'Agrifood Systems and Bioeconomy'," funded by the European Regional Development Fund through the Bulgarian Operational Programme "Programme for Research, Innovation and Digitalisation for Smart Transformation" (PRIDST). The authors also acknowledge the use of ChatGPT (OpenAI) to generate the infographic visualization based on the authors' original text and concept.

Author Contributions

Conceptualization, M.I. and A.B.; methodology, M.I. and A.B.; review analysis T.B.,P.B.,M.D.D. and I.I.; investigation, T.B.,P.B.,M.D.D. and I.I.; resources, T.B.,P.B.,M.D.D. and I.I.; data curation, M.I. and A.B.; writing – original draft preparation, M.I.; writing – T.B.,P.B.,M.D.D. and I.I., review and editing, M.I. and A.B.; visualization, M.I; supervision, T.B.,P.B., M.D.D. and I.I.; project administration, M.I; funding acquisition, M.I. All authors have read and agreed to the published version of the manuscript.

Funding

This research was funded by the project BG16RFPR002-1.014-0012-C01 „Establishment and sustainable development of a Center of Competence „Agrifood Systems and Bioeconomy", financed by the European Regional Development Fund through the „Program for Research, Innovation and Digitalisation for Smart Transformation"(PRIDST).

Institutional Review Board Statement

The experimental protocol used in this study was designed in compliance with the guidelines of the European and Bulgarian legislation regarding the protection of animals used for experimental and other scientific purposes (Directive 2010/63; EC, 2010 - put into law in Bulgaria with Regulation 20/2012). The protocol was based on the permit for the use of animals in experiments No. 277 of the Bulgarian Food Safety Agency (Statement No. 193 of the Bulgarian Animal Ethics Committee, prot.No.18/02.07.2020, 2 July 2020).

Informed Consent Statement

Not applicable.

Data Availability Statement

The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding authors.

Conflicts of Interest

The authors declare no conflicts of interest.

References

Abd Elhamid A. Physicochemical, rheological and sensory properties of Egyptian Kariesh cheese containing wheat bran. *International Journal of*

Dairy Technology, 2016, 69(3): 425-432. https://doi.org/10.1111/1471-0307.12278

Agourram A., Ghirardello D., Rantsiou K., Zeppa G., Belviso S., Romane, A., Giordano M. Phenolic content, antioxidant potential, and antimicrobial activities of fruit and vegetable by-product extracts. *International Journal of Food Properties*, 2013, 16(5): 1092-1104. https://doi.org/10.1080/10942912.2011.576446

Ahmad T., Esposito F., Cirillo T. Valorization of agro-food by-products: Advancing sustainability and sustainable development goals 2030 through functional compounds recovery. *Food Bioscience*, 2024, 62(12): 105194. https://doi.org/10.1016/j.fbio.2024.105194

Alqahtani A., Aljuraiban G., Alshammari G. Effect of tomato pomace addition on the physicochemical, rheological, and microbiological properties of set yogurt. *Journal of Food Science and Nutrition*, 2020, 8(11): 6023-6032. http://doi.org/10.1002/fsn3.1892

Arab M., Sadoudi R., Kaci G. Effect of carob pulp supplementation on physicochemical, antioxidant and probiotic properties of yogurt during storage. *Journal of Food Measurement and Characterization*, 2022, 16(2): 1354-1365. http://doi.org/10.1007/s11694-021-01234-7

Ariza M., Reboredo-Rodríguez P., Cervantes L., Soria C., Martínez-Ferri E., González-Barreiro C., Cancho-Grande B., Battino M., Simal-Gándara J. Bioaccessibility and potential bioavailability of phenolic compounds from achenes as a new target for strawberry breeding programs. *Food Chemistry*, 2018, 248(5): 155-165. https://doi.org/10.1016/j.foodchem.2017.11.105

Awda J., Awad H., Alssirag M., Alfalahi, D. Extend the shelf life and improving sensory properties of white soft cheese by adding celeryleaves. *Iraqi Journal of Agricultural Sciences*, 2019, 50: 1661-1667. Available at: https://jcoagri.uobaghdad.edu.iq/index.php/intro/article/view/857

Baker M., Lu P., Parrella, J., Leggette, H. Consumer acceptance toward functional foods: A scoping review. *International Journal of Environmental Research and Public Health*, 2022, 19(3): 1217. https://doi.org/10.3390/ijerph19031217

Barbaccia P., Busetta G., Barbera M., Alfonzo A., Garofalo G., Francesca N., Moscarelli A., Moschetti G., Settanni L., Gaglio R. Effect of grape pomace from red cultivar 'Nero d'Avola' on the microbiological, physicochemical, phenolic profile, and sensory aspects of ovine Vastedda-like stretched cheese. *Journal of applied microbiology*, 2022, 133(1): 130-144. https://doi.org/10.1111/jam.15354

Belović M., Torbica A., Pajić Lijaković I., Tomić J., Lončarević I., Petrović J. Tomato pomace powder as a raw material for ketchup production. *Food Bioscience*, 2018, 26(12): 193-199. https://doi.org/10.1016/j.fbio.2018.10.013

Bendini A., Di Lecce G., Valli E., Barbieri S., Tesini F., Gallina Toschi T. Olive oil enriched in lycopene from tomato by-product through a co-milling process. *International Journal of Food Science and Nutrition*, 2014; 66(4): 371-377. http://doi.org/10.3109/09637486.2015.1035230

Brassesco M. Nutritional and functional properties of carob (*Ceratonia siliqua* L.). *Journal of Food Composition and Analysis*, 2021, 96(3): 103709. http://doi.org/10.1016/j.jfca.2020.103709

Buzzanca C., Caruso M., Licciardello F. Carob-based ingredients as functional sweeteners in dairy products. *Foods*, 2024, 13(2): 215. http://doi.org/10.3390/foods13020215

Çakır E., Bekiroğlu H., Çakır M., Sağdıç O. 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. https://doi.org/10.29050/harranziraat.1652328

Cangussu L., Leão D., Oliveira L., Franca A. Profile of bioactive compounds in pequi (*Caryocar brasilense Camb*.) peel flours. *Food Chemistry*, 2021, 350(7): 129221. https://doi.org/10.1016/j.foodchem.2021.129221

Carnaval L., Jaiswal A., Jaiswal S. Agro-Food Waste Valorization for Sustainable Bio-Based Packaging. *Journal of Composites Science*. 2024, 8(2): 41. https://doi.org/10.3390/jcs8020041

Castillejo N., Martínez-Zamora L. Bioactive compounds from fruit and vegetable waste: extraction and possible utilization. *Foods*, 2024, 13(5): 775. https://doi.org/10.3390/foods13050775

Christaki S., Moschakis T., Kyriakoudi A., Biliaderis C., Mourtzinos, I. Recent advances in plant essential oils and extracts: Delivery systems and potential uses as preservatives and antioxidants in cheese. *Trends in Food Science and Technology*, 2021, 116(10): 264-278. https://doi.org/10.1016/j.tifs.2021.07.029

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

Covaliov E., Capcanari T., Resitca V., Chirsanova A., Boistean A., Sturza R., Patras A., Pocol C., Ruseva O., Chioru A. Exploring the biological value of red grape skin: its incorporation and impact on yogurt quality. *Foods*, 2024, 13(20): 3254. https://doi.org/10.3390/foods13203254

Demirci T., Aktaş K., Akın N. Effects of tomato powders produced by different processing techniques on probiotic yogurt quality. *Journal of Dairy Science*, 2020, 103(4): 2985-2997. http://doi.org/10.3168/jds.2019-17688

Difonzo G., Antonino C., Squeo G., Caponio F., Faccia M. Application of Agri-Food By-Products in *Cheesemaking*. *Antioxidants*, 2023, 12(3): 660. https://doi.org/10.3390/antiox12030660

Difonzo G., Crescenzi M., Piacente S., Altamura G., Caponio F., Montoro P. Metabolomics approach to characterize green olive leaf extracts classified based on variety and season. *Plants*, 2022, 11(23): 3321. https://doi.org/10.3390/plants11233321

Dimitrova M., Ivanov G., Mihalev K., Slavchev A., Ivanova I., Vlaseva R. Investigation of antimicrobial activity of polyphenol-enriched extracts against probiotic lactic acid bacteria. *Food Science and Applied Biotechnology*, 2019, 2(1): 67. https://doi.org/10.30721/fsab2019.v2.i1.57

Ebid W., Mabrouk A. Physicochemical and microbiological properties of functional Labneh fortified with mandarin peel powder during refrigeration storage. *International Journal of Food Science and Nutrition*, 2022, 7(1): 46-53. Available at: https://journals.indexcopernicus.com/api/file/viewByFileId/1795045

El-Dardiry A. Impact of carrot pomace paste (*Daucus carota* L.) addition on some properties of processed cheese. *Egyptian Journal of Applied Science*, 2021, 36: 16-28. https://doi.org/10.21608/ejas.2021.195258

Elkot W.F., Ismail H.A. Technological advances in functional dairy foods and their role in human nutrition: A review. *Aswan Journal of Agricultural and Biological Sciences*, 2025, 1(1): 24-33. https://doi.org/10.21608/ajabs.2025.397996.1005

Elmehrach K., Aït-Kaddour A., Kaci G. Influence of carob flour and starch on the physicochemical and rheological properties of yogurt. *International Journal of Dairy Technology*, 2019, 72(3): 430-438. http://doi.org/10.1111/1471-0307.12615

El-Messery T., El-Said M., Farahat E. Production of functional processed cheese supplemented with nanoliposomes of mandarin peel extract. *Pakistan Journal of Biological Science*, 2019, 22(5): 247-256. https://doi.org/10.3923/pjbs.2019.247.256

Froiio F., Ginot L., Huguet M. Rheological and functional properties of dairy systems enriched with carob fiber. *Food Hydrocolloids*, 2020, 101(4): 105474. http://doi.org/10.1016/j.foodhyd.2019.105474

Frühbauerová M., Cervenka L., Hájek T., Salek R., Velichová H., Bŭnka F. Antioxidant properties of processed cheese spread after freeze-dried and oven-dried grape skin powder addition. *Potravinarstvo Slovak Journal of Food Sciences*, 2020, 14(4): 230-238. https://doi.org/10.5219/1310

Gaglio R., Barbaccia P., Barbera M., Restivo I., Attanzio A., Maniaci G., Di Grigoli A., Francesca N., Tesoriere L., Bonanno A. The use of winery by-products to enhance the functional aspects of the fresh ovine "primosale" cheese. *Foods*, 2021, 10(2): 461. https://doi.org/10.3390/foods10020461

Galanakis C. Recovery of high added-value components from food wastes: Conventional, emerging technologies and commercialized applications. *Trends in Food Science and Technology*, 2012, 26(2): 68-87. https://doi.org/10.1016/j.tifs.2012.03.003

Gobindram M., Bognanno M., Luciano G., Lanza M., Biondi L. Carob pulp inclusion in lamb diets: effect on intake, performance, feeding behaviour and blood metabolites. *Animal Production Science*, 2015, 56(5) : 850-858. https://doi.org/10.1071/an14733

Granato D., Barba F., Kovačević D., et al. Functional Foods: Product Development, Technological Trends, Efficacy Testing, and Safety. *Annual Review of Food Science and Technology*, 2020, 11: 93-118. https://doi.org/10.1146/annurev-food-032519-051708

Grillia M., Naziri E. Sustainable utilization of whole tomato powder as a food waste ingredient in yogurt manufacture. *Journal of Cleaner Production*, 2026, 409(7): 137240. http://doi.org/10.1016/j.jclepro.2023.137240

Guclu G., Kelebek H., Selli S. Antioxidant Activity in Olive Oils. In: *Olives and Olive Oil in Health and Disease Prevention* (Second Edition). Academic Press: Cambridge, MA, USA. 2021; pp. 313-325, ISBN: 978-0-12-819528-4, https://doi.org/10.1016/B978-0-12-819528-4.00031-6

Güler-Akin M., Akin M., Korkmaz A. Influence of carob extract on probiotic viability and physicochemical properties of yogurt. *Journal of Food Science and Technology*, 2016, 53(2): 1115-1122. http://doi.org/10.1007/s13197-015-2152-9

Gyawali R., Ibrahim S. Addition of pectin and whey protein concentrate minimizes the generation of acid whey in Greek-style yogurt. *Journal of Dairy Research*, 2018, 85(2): 238-242. http://doi.org/10.1017/S0022029918000198

Hamam M., Chinnici G., Di Vita G., Pappalardo G., Pecorino B., Maesano G., D'Amico M. Circular Economy Models in Agro Food Systems: A Review. *Sustainability*, 2021, 13(6): 3453. https://doi.org/10.3390/su13063453

Hassan F., Zaky W., Farahat E., Zayan A., Mohamed A., AbdulAlim T. Processed Cheese Spreads Fortified with Lycopene. *World Journal of Dairy*

and Food Sciences, 2019, 14(1): 87-93. https://doi.org/10.5829/idosi.wjdfs.2019.87.93

Ikram A., Shahbaz M., Rashid S. Carob (*Ceratonia silig*ua L.): A functional ingredient with nutraceutical potential. *Food Reviews International*, 2023, 39(6): 3135-3152. http://doi.org/10.1080/87559129.2022.2031924

Iriondo-DeHond M., Miguel E., Del Castillo M. Food Byproducts as Sustainable Ingredients for Innovative and Healthy Dairy Foods, *Nutrients*, 2018, 10(10): 1358. https://doi.org/10.3390/nu10101358

Jefrin. J, A., R S, K., Kumar. A, P., & g, R. (2022). Development of yogurt enriched with freeze dried tomato peel powder. *International Journal of Engineering Applied Sciences and Technology*, 7(5): 192–198. https://doi.org/10.33564/ijeast.2022.v07i05.03

Kandyliari A., Mallouchos A., Papastergiadis A. Valorization of plant-based food by-products in dairy matrices: A review. *Foods*, 2023, 12(7): 1412. http://doi.org/10.3390/foods12071412

Kandylis P., Dimitrellou D., Moschakis T. Recent applications of grapes and their derivatives in dairy products. Trends in Food Science and Technology, 2021, 114(8): 696-711. https://doi.org/10.1016/j.tifs.2021.05.029

Karababa E., Coşkunder Y. Composition and technological properties of carob products. *Journal of Food Processing and Preservation*, 2013, 37(4): 321-330. http://doi.org/10.1111/j.1745-4549.2011.00637.x

Kaur D., Wani A., Singh D. Sogi D. Shelf life enhancement of butter, ice-cream, and mayonnaise by addition of lycopene. *International Journal of Food Properties*, 2011, 14(6): 1217-1231. https://doi.org/10.1080/10942911003637335

Tariq Khal N., Ali Mosa M. Effect of Wheat Germ on Chemical, Sensory and Technological Properties of Soft Cheese. *International Journal of Dairy Science*, 2017, 13(1): 40-45. https://doi.org/10.3923/ijds.2018.40.45

Khalil M., El-Wahed A., Shalaby H., Gaballa A. Production of feta like cheese fortified with pomegranate and lemon peels extract as natural antioxidants. *Zagazig Journal of Agricultural Research*, 2019, 46: 710-720. https://doi.org/10.21608/zjar.2019.40956

Khan I., Nadeem M., Imran M., Ajmal M., Ali S. Antioxidant activity, fatty acids characterization and oxidative stability of Gouda cheese fortified withmango (*Mangifera indica* L.) kernel fat. *Journal of Food Science and Technology*, 2018, 55(3): 992-1002. https://doi.org/10.1007/s13197-017-3012-y

Leal M., Albuquerque P., Rodrigues N., dos Santos Silva P., de Oliveira W., dos Santos Correia M., Kennedy J., Coelho L. A review on the use of polysaccharides as thickeners in yogurts. *Carbohydrate Polymer Technologies and Applications*, 2024, 8(12): 100547. http://doi.org/10.1016/j.carpta.2024.100547

Ligarda-Samanez C., Huamán-Carrión M., Calsina-Ponce W. Technological innovations and circular economy in the valorization of agri food by products: advances, challenges and perspectives. *Foods*, 2025, 14(11): 1950. https://doi.org/10.3390/foods14111950

Lucera A., Costa C., Marinelli V., Saccotelli M., Del Nobile M., Conte. Fruit and vegetable by-products to fortify spreadable cheese. *Antioxidants*, 2018, 7(5): 61. https://doi.org/10.3390/antiox7050061

Mahajan D., Bhat Z., Kumar S. Pomegranate (*Punica granatum*) rind extract as a novel preservative in cheese. *Food Bioscience*, 2015, 12(12): 47-53. https://doi.org/10.1016/J.FBIO.2015.07.005

Marchiani R., Bertolino M., Ghirardello D., McSweeney P., Zeppa G. Physicochemical and nutritional qualities of grape pomace powder-fortified semi- hard cheeses. *Journal of Food Science and Technology*, 2016, 53(3): 1585-1596. https://doi.org/10.1007/s13197-015-2105-8

Martins N., Oliveira M., Ferreira I. Development of Functional Dairy Foods. In: *Bioactive Molecules in Food*, (J.M. Mérillon, K. Ramawat Eds.). Reference Series in Phytochemistry, Springer, Cham. 2019, pp. 1-12, Series ISSN 2511-834X, Series E-ISSN 2511-8358. https://doi.org/10.1007/978-3-319-54528-8_35-1

Masmoudi M., Ammar I., Ghribi H., Attia H. Physicochemical, radical scavenging activity and sensory properties of a soft cheese fortified with *Arbutus unedo* L. extract. *Food Bioscience*, 2020, 35: 100579. https://doi.org/10.1016/j.fbio.2020.100579

Matei E., Râpă M., Predescu A., Andreea A. Valorization of agri-food wastes as sustainable eco-materials for wastewater treatment: current state and new perspectives. materials, 2021, 14(16): 458. https://doi.org/10.3390/ma14164581

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

Mileriene J., Serniene L., Kondrotiene K., Lauciene L., Kasetiene N., Sekmokiene D. Quality and nutritional characteristics of traditional curd cheese enriched with thermo-coagulated acid whey protein and indigenous *Lactococcus lactis* strain. *International Journal of Food Science and Technology*, 2021, 56(6): 2853-2863. https://doi.org/10.1111/IJFS.14922

Mirabella N., Castellani V., Sala S. Current options for the valorization of food manufacturing waste: a review. *Journal of Cleaner Production*, 2014, 65(2): 28-41. https://doi.org/10.1016/j.jclepro.2013.10.051

Moreira R., Costa M., Castro V., Paes C., Mutz Y., Frasao B., Mano S., Conte-Junior C. Antimicrobial activity of pequi (*Caryocar brasiliense*) waste extract on goat Minas Frescal cheese presenting sodium reduction. *Journal of Dairy Science*, 2019, 102(4): 2966-2972. https://doi.org/10.3168/jds.2018-15268

Mushtaq M., Gani A., Gani A., Punoo H., Masoodi F. Use of pomegranate peel extract incorporated zein film with improved properties for prolonged shelf life of fresh Himalayan cheese (Kalari/Kradi). *Innovative Food Science and Emerging Technologies*, 2018, 48(8): 25-32. https://doi.org/10.1016/j.ifset.2018.04.020

Natalello A., Priolo A., Valenti B., Codini M., Mattioli S., Pauselli M., Luciano G. Dietary pomegranate by-product improves oxidative stability of lamb meat, *Meat Science*. 2020, 162(4): 108037. https://doi.org/10.1016/j.meatsci.2019.108037

Özbek C., Özdemir Y. Revitalizing traditional Turkish tort cheese into spreadable form: Enhancing bioactive and sensory attributes with utilization of carob molasses pulp that is a food waste. *Food science and Nutrition*, 2024, 12(8): 6034-6044. https://doi.org/10.1002/fsn3.4239

Parafati L., Pesce F., Siracusa L., Fallico B., Restuccia C., Palmeri R. Pomegranate by-product extracts as ingredients for producing experimental cheese with enhanced microbiological, functional, and physical characteristics. *Foods*, 2021, 10(11): 2669. https://doi.org/10.3390/foods10112669

Picciotti U., Massaro A., Galiano A., Garganese F. Cheese fortification: Review and possible improvements. *Food Reviews International*, 2022, 38(S1): 474-500. https://doi.org/10.1080/87559129.2021.1874411

Popescu L., Cesco T., Gurev A., Ghendov-Mosanu A., Sturza R., Tarna R. Impact of apple pomace powder on the bioactivity, rheology and sensory properties of yoghurt. *Foods*, 2022, 11(22): 3565. https://doi.org/10.3390/foods11223565

Popescu L., Cojocari D., Ghendov-Mosanu A., Lung I., Soran M-L., Opris O., Kacso I., Ciorița A., Balan G., Pintea A., Sturza R. The effect of aromatic plant extracts encapsulated in alginate on the bioactivity, textural characteristics and shelf life of yogurt. *Antioxidants*, 2023a, 12(4): 893. http://doi.org/10.3390/antiox12040893

Popescu L., Cojocari D., Lung I., Kacso I., Ciorița A., Ghendov-Mosanu A., Balan G., Pintea A., Sturza R. Effect of microencapsulated basil extract on cream cheese quality and stability. *Molecules*, 2023b, 28(8): 3305. http://doi.org/10.3390/molecules28083305

Posseti T., de Oliveira Santos W., Malpass G., Okura M., Granato A. Extraction, chemical composition of peel and kernel mango extracts and their antimicrobial effect on the production and characteristics of Minas frescal cheese. *Revista do Instituto de Laticínios Cândido Tostes*, 2020, 75(4): 251-265. https://doi.org/10.14295/2238-6416.v75i4.832

Priyanka G., Singiri J., Adler-Agmon Z., Sannidhi S, Daida S., Novoplansky N., Grafi G. Detailed analysis of agro-industrial byproducts/wastes to enable efficient sorting for various agro-industrial applications. *Bioresour Bioprocess*, 2024, 11(1): 45. https://doi.org/10.1186/s40643-024-00763-7

Ranveer R., Sahoo A. Developments of lycopene enrich noodles. *South Asian Journal of Management Research*, 2015, 6(1): 461-470. Available at: https://siberindia.edu.in/journals/SAJMR/Jan-2014/Paper-2.pdf

Rațu R., Velescu I., Stoica F., Usturoi Al. Application of agri-food by-products in the food industry. *Agriculture*, 2023, 13(8): 1559. https://doi.org/10.3390/agriculture13081559

Rizk E., El-Kady A., El-Bialy A. Utilization of carotenoids extracted from tomato peels as natural colorants and antioxidants in ice cream. *Annals of Agricultural Sciences*, 2014, 59(1): 53-61. https://doi.org/10.1016/j.aoas.2014.06.008

Roila R., Valiani A., Ranucci D., Ortenzi R., Servili M., Veneziani G., Branciari R. Antimicrobial efficacy of a polyphenolic extract from olive oil by-product against "Fior di latte" cheese spoilage bacteria. *International Journal of Food Microbiology*, 2019, 295(4): 49-53. https://doi.org/10.1016/j.ijfoodmicro.2019.02.013

Roxana R., Stoica F., Crivei I. Valorisation of fruit and vegetable by-products in dairy product technologies: a sustainable approach to functional food development. *In book: Food Processing - Novel Technologies and Practices*, 2025, 10. https://doi.org/10.5772/intechopen.1013256

Ruseva N., Gogova T., Vladeva S., Hristov B. Bread designed for impaired glucose metabolism, recipe composition and protein enrichers for it. *Food Science and Applied Biotechnology*, 2024, 7(2): 278. https://doi.org/10.30721/fsab2024.v7.i2.326

Sagar N., Pareek S., Sharma S., Yahia E.M., Lobo M.G. Fruit and vegetable waste: Bioactive compounds, their extraction, and possible utilization. *Comprehensive Reviews in Food Science and Food Safety*, 2018, 17(3): 512-531. https://doi.org/10.1111/1541-4337.12330

Sandhya S., Khamrui K., Prasad W., Kumar M. Preparation of pomegranate peel extract powder and

evaluation of its effect on functional properties and shelf life of curd. *LWT – Food Science and Technology*, 2019, 92(6): 416-421. https://doi.org/10.1016/j.lwt.2018.02.057

Savadkoohi S., Hoogenkamp H., Shamsi K., Farahnaky A. Color, sensory and textural attributes of beef frankfurter, beef ham and meat-free sausage containing tomato pomace. *Meat Science*, 2014, 97(4): 410-418. https://doi.org/10.1016/j.meatsci.2014.03.017

Šelo G., Planinić M., Tišma M., Tomas S., Komlenić D. K., Bucić-Kojić A. A comprehensive review on valorization of agro-food industrial residues by solid-state fermentation. *Foods*, 2021, 10(5): 927. https://doi.org/10.3390/foods10050927

Sendra E., Fayos P., Lario Y., Fernández-López J., Sayas-Barberá E., Pérez-Alvarez J.A. Incorporation of citrus fibers in fermented milk containing probiotic bacteria. *Food Microbiology*, 2010, 27(4): 499-505. http://doi.org/10.1016/j.fm.2010.01.007

Serna-Cock L., García-Gonzales E., Torres-Léon C. Agro-industrial potential of the mango peel based on its nutritional and functional properties. *Food Reviews International*, 2016, 32(4): 364-376. https://doi.org/10.1080/87559129.2015.1094815

Sharma S., Maguer M. Lycopene in tomatoes and tomato pulp fractions. *Italian Journal of Food Science*, 1996, 8(2): 107-113.

Shi J. Lycopene in tomatoes: Chemical and physical properties affected by food processing. *Critical Reviews in Food Science and Nutrition*, 2000, 40(1): 1-42. http://doi.org/10.1080/10408690091189275

Silva L., Jacinto T., Coutinho P. Bioactive compounds from cardoon as health promoters in metabolic disorders. *Foods*, 2022, 11(3): 336. https://doi.org/10.3390/foods11030336

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

Staffolo M., Bertola N., Martino M., Bevilacqua A. Influence of dietary fiber addition on sensory and rheological properties of yogurt. *International Dairy Journal*, 2004, 14(3): 263-268. http://doi.org/10.1016/j.idairyj.2003.08.002

Sukhikh S.A., Astakhova L.A., Golubtsova Y.V., Lukin A.A., Prosekova E.A., Milenteva I.S., Kostina N.G., Rasshchepkin A.N. Functional dairy products enriched with plant ingredients. *Foods and raw materials*, 2019, 7(2): 428-438. http://doi.org/10.21603/2308-4057-2019-2-428-438

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. Valorization of agri-food waste and by-products in cheese and other dairy foods: An updated review. *Food Bioscience*, 2024, 58(4): 103751. https://doi.org/10.1016/j.fbio.2024.103751

Terpou A., Bekatorou A., Bosnea L., Kanellaki M., Ganatsios V., Koutinas A. Wheat bran as prebiotic cell immobilisation carrier for industrial functional Feta-type cheese making: Chemical, microbial and sensory evaluation. *Biocatalysis and Agricultural Biotechnology*, 2018, 13(1): 75-83. https://doi.org/10.1016/j.bcab.2017.11.010

Torres-Léon C., Ramírez-Guzman N., Londoño-Hernandez L., Martinez-Medina G., Díaz-Herrera R., Navarro-Macias V., Alvarez-Pérez O., Picazo B., Villarreal-Vazquez M., Ascacio-Valdes J., Aguilar C. Food waste and byproducts: An opportunity to minimize malnutrition and hunger in developing countries. *Frontiers in Sustainable Food Systems*, 2018, 2(9): 52. https://doi.org/10.3389/fsufs.2018.00052

Torri L., Piochi M., Marchiani R., Zeppa G., Dinnella C., Monteleone E. A sensory- and consumer-based approach to optimize cheese enrichment with grape skin powders. *Journal of Dairy Science*, 2016, 99(1): 194-204. https://doi.org/10.3168/jds.2015-9922

Tripathi S., Mishra S. Antioxidant, antibacterial analysis of pectin isolated from banana peel and its application in edible coating of freshly made mozzarella cheese. *Asian Food Science Journal*, 2021, 20(7): 82-92. https://doi.org/10.9734/afsj/2021/v20i730324

Tseng A., Zhao Y. Wine grape pomace as antioxidant dietary fiber for enhancing nutritional value and improving storability of yogurt and salad dressing. *Food Chemistry*, 2013, 138(1): 356-365. http://doi.org/10.1016/j.foodchem.2012.10.088

Vital A., Croge C., Gomes-da-Costa S., Matumoto-Pintro P.T. Effect of addition of by-products on physicochemical and sensory properties of dairy products. *LWT – Food Science and Technology*, 2015, 64(1): 302-309. http://doi.org/10.1016/j.lwt.2015.05.046

Zayan A., Bakry A., AbdulAlim T., Radwan H., Abouelnaga M., Safdar W., Campelo H., Rashed M., Rahman R., Muhammad Z. Novel processed cheese production using lycopene oil obtained by green-extraction technique of tomato peels waste. *Journal of Nutrition and Food Processing*, 2021, 4(1): 35. https://doi.org/10.31579/2637-8914/035

Zuorro A., Lavecchia R., Medici F., Piga L. Enzyme-assisted production of tomato seed oil enriched with lycopene from tomato pomace. *Food and Bioprocess Technology*, 2013, 6(12): 3499-3509. http://doi.org/10.1007/s11947-012-1003-6