

## Effect of fresh and dried broccoli (*Brassica oleracea* var. *italica*) florets and stems on properties of camel kefir

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Academic Editor: Prof. Fernanda Galgano – University of Basilicata, Italy

Received: 8 July 2025; Accepted: 3 December 2025; Published: 8 January 2026

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OPEN ACCESS 

ORIGINAL ARTICLE

### Abstract

In the present study, the effect of the addition of fresh and dried broccoli florets and stems to kefir samples produced from camel milk with a rich nutrient profile on physicochemical and biochemical properties was investigated. Statistically very significant ( $p < 0.01$ ) differences were determined between the kefir samples in terms of antioxidant activity, organic acids, Na and some phenolic compounds. It was revealed that fresh and dried broccoli stems, which are evaluated as waste, provide positive contributions to camel kefir in terms of bioactive components and antioxidant capacity and, in some cases, are even superior to broccoli florets.

*Keywords:* antioxidant activity, bioactive components, broccoli florets, broccoli stems, camel kefir, drying process

### Introduction

In the dairy industry, which is mostly dominated by cow's milk globally, the possibility of not being able to meet the demands of the rapidly growing population is a serious concern (Kumar *et al.*, 2016; Ali *et al.*, 2019). In this respect, various alternative milk sources have been evaluated in recent years, and camel milk, which was seen as a local food source in the past and could not find the value it deserved in the dairy industry, has attracted attention due to its immune-enhancing proteins (immunoglobulins and lactoferrin), minerals (Fe and Ca) and vitamins (vitamin C and D) (Ait El Alia *et al.*, 2025). In addition to its high nutritional value, camel milk is an indispensable part of a healthy diet due to its low-fat content and easy digestibility (Abdelazez *et al.*, 2024). Camel milk, which is an alternative protein source for lactose-intolerant individuals, can be pasteurized or converted into fermented dairy products to improve its existing properties, increase the utilization of its nutraceutical and functional properties and extend its shelf life (Terzioğlu *et al.*, 2023). The fact that camel milk and fermented products produced from camel milk play an important role in the prevention of many health problems, especially cardiovascular diseases, autism, diabetes and allergies, is a major factor in camel milk and its products becoming the center of attention (Al-Ayadhi *et al.*, 2015; Ho *et al.*, 2022; Sakandar *et al.*, 2018). The use of camel milk products, a natural resource, instead of synthetic drugs with possible side effects in the treatment of various diseases is an important step for the pharmaceutical industry (Kumar *et al.*, 2022; Almasri *et al.*, 2024).

In addition, fruits and vegetables also have an important place as natural sources of bioactive compounds to replace synthetic drugs (Ahmed *et al.*, 2025). Unfortunately, about 45% of fruits and vegetables, which also have an important place in human health and nutrition, are reported to be lost at all stages of the food supply chain (Sharma *et al.*, 2021). In fact, it is reported that more than 40% of these losses in developed countries occur through wastage at the retail and consumer levels, while 40% of these losses in developing countries occur during post-harvest processing stages due to reasons such as improper agricultural practices, inappropriate transportation methods and inadequate storage areas (Thomas *et al.*, 2018; Anand and Barua, 2022). As a result of these food losses and waste, a significant amount of food waste is generated and, especially in recent years, global- and local-based policies covering agricultural waste management and sustainable food supply have been developed to incorporate fruit and vegetable waste back into consumption processes. Reducing post-harvest losses, minimizing food waste per capita, using natural resources efficiently and reusing food waste are among the United Nations Sustainable Development Goals for 2030 (Rajković *et al.*, 2020).

Broccoli (*Brassica oleracea* var. *italica*), a member of the Brassicaceae family, is a vegetable with anti-inflammatory, antioxidant and anticancer properties due to its rich content of bioactive compounds such as polyphenols (including hydroxycinnamic acids and flavonoids), glucosinolates and their degradation products, minerals (such as potassium and manganese), vitamins (ascorbic acid) and dietary fibers (Gudiño *et al.*, 2024). Currently, only the flowers of broccoli are utilized, and the leaves and stems, which are rich in vitamins and minerals as well as bioactive compounds such as phenolic compounds and carotenoids, are classified as waste and constitute about 47% of broccoli (Bas-Bellver *et al.*, 2024). The broccoli stalk, which is considered to be about 10 cm below the broccoli flower, generally has a hard structure due to its thickened vascular cell walls, and the edibility and softness of the stalk increase as they approach the flower. It is predicted that the utilization of broccoli stems, which are considered waste, will increase sustainability and broccoli production by 15–83% worldwide (Muller *et al.*, 2003; Liu *et al.*, 2018). The broccoli stem, which is not widely consumed, is a source of high fiber and is also prominent in terms of health and nutrition due to its anticancer and antioxidant properties (Bhandari and Kwak, 2014; Hwang and Lim, 2015). Broccoli florets are reported to exhibit anticancer properties through the glucosinolates they contain (Clarke *et al.*, 2008). Glucosinolates, which are inactive in the cell, react with the myrosinase enzyme and break down into bioactive isothiocyanates. Glucoraphanin, which belongs to the glucosinolate class,

acts as a precursor of sulforaphane and is converted into sulforaphane, an isothiocyanate that inhibits the growth of cancerous cells as well as tumors located in the body (Li and Zhang, 2013). In addition, broccoli florets exhibit antioxidant, antimutagenic and antiviral properties through the chlorophylls they contain and also show positive effects against cardiovascular diseases and cancer through their carotenoid content (Liu *et al.*, 2018).

Reducing the moisture content of various parts of plants such as broccoli from approximately 80–90% to 10–20% by drying, in other words, significantly reducing water activity, is of great importance for reducing the rate of undesirable reactions in the product, slowing down microbial activity and preserving properties such as nutritional value, odor and taste (Aral and Beşe, 2016; Zhao *et al.*, 2025). At the same time, the high moisture content of broccoli and broccoli by-products, which are dried and pulverized by different drying processes such as hot air drying, freeze drying and microwave drying, is reduced, thereby facilitating processing, storage and transportation stages, increasing usability as a high-value supplement and standardizing its texture and appearance commercially (Dufoo-Hurtado *et al.*, 2018; Xu *et al.*, 2020). Hot air drying is preferred more often than other methods in the food industry due to its low cost, simple equipment and sustainability with a low carbon footprint; however, this drying method can also cause some undesirable phenomena such as color loss and degradation of heat-sensitive ingredients (Zhang *et al.*, 2019; Karwacka *et al.*, 2020; Tan *et al.*, 2022).

As a result of our research, although there are some studies on camel kefir, broccoli by-products and drying methods in the literature (Liu *et al.*, 2018; Baniasadi *et al.*, 2022; Muelas *et al.*, 2022; Núñez-Gómez *et al.*, 2022; Arroum *et al.*, 2025; Zhao *et al.*, 2025), there is no study investigating the effect of adding fresh and dried broccoli florets and stems to camel kefir on the phenolic compound profile, organic acid profile, mineral content and antioxidant activity. In this respect, the addition of fresh and dried broccoli florets and stems to camel kefir, which is a unique source and exhibits probiotic properties due to the microorganisms it contains, offers important opportunities in terms of waste utilization, developing a new product with high health potential and revealing the effect of the drying process on antioxidant and bioactive compounds. In the present study, it was aimed to investigate the physicochemical and biochemical properties in detail by adding 1% fresh and dried broccoli florets and stems to kefir samples produced from camel milk. For this purpose, kefir samples were analyzed for total solids, ash, titratable acidity, DPPH, ABTS, phenolic compound profile, organic acid profile and mineral matter.

## Materials and Methods

### Material

Raw camel milk used in kefir production was obtained from local farms in Denizli (Türkiye), and broccoli florets and stems used as additives in kefir production were obtained from local grocery stores in Erzurum (Türkiye). Commercial kefir culture (*Lactococcus lactis* subsp. *lactis*, *Streptococcus thermophilus*, *Lactococcus lactis* subsp. *lactis* var. *diacetylactis*, *Leuconostoc mesenteroides* subsp. *cremoris*, *Lactococcus lactis* subsp. *cremoris*, *Debaryomyces hansenii* and *Kluyveromyces marxianus* subsp. *marxianus*) was purchased from VIVO Food Industry and Trade Limited Company (Istanbul, Türkiye).

### Method

#### Preparation of dried broccoli florets and stems

Broccoli florets and stems were cleaned and dried in an oven (Beko, Türkiye) at 40°C. The dried broccoli florets and stems were ground using a coffee grinder (Bosch, TSM6A013B, 180 W) and powdered through a sieve (500 µm).

#### Kefir production

Raw camel milk was pasteurized at 90°C for 10 min and then cooled to 45°C. As a result of a literature review (Gül *et al.*, 2023; Barazi and Arslan, 2024) and preliminary trials (preservation of consistency and homogeneous structure), various additive ratios were taken into consideration, and the addition rate of broccoli florets and stems in the kefir samples was preferred as 1%. Fresh and dried broccoli florets and stems were added to the samples at 1%, except for the control group sample, at 45°C. All samples were cooled to 32°C for inoculation with commercial kefir culture. After inoculation, all samples were placed in an incubator (Memmert, IN55) and incubated at 25°C until the pH reached 4.6. The kefir samples produced are presented in Figure 1. In this context, the samples are coded as D: Control camel kefir, FBF: Camel kefir with fresh broccoli florets, FBS: Camel kefir with fresh broccoli stems, DBF: Camel kefir with dried broccoli florets and DBS: Camel kefir with dried broccoli stems.

#### Physicochemical analyses

Total solids (%), ash (%) and titratable acidity analyses of kefir samples produced from camel milk were performed according to the method given by Terzioğlu *et al.* (2024).

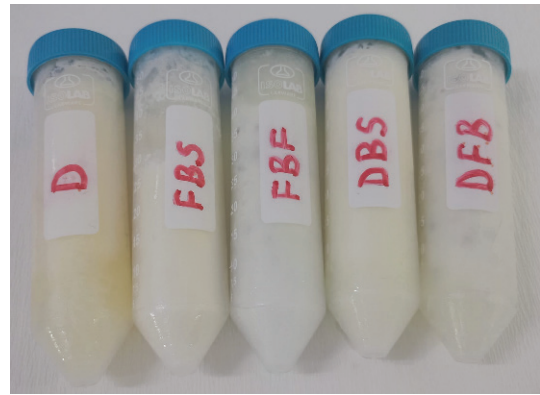


Figure 1. Kefir samples.

#### Antioxidant activity

Extracts were prepared for DPPH (1,1-diphenyl-2-picrylhydrazyl) free radical scavenging activity and ABTS (2,2'-azino-bis-3-ethylbenzothiazoline-6-sulphonic acid) radical scavenging activity assays. During extraction, a volume of 3 mg sample was made up to 30 mL with methanol, centrifuged at 6000 rpm for 15 min and filtered (Whatman No. 2) (Ciniviz and Yildiz, 2020). For DPPH free radical scavenging activity, the extract volume was made up to 2 mL with methanol and homogenized by adding 0.5 mL DPPH solution. Absorbance was then measured at 537 nm using a spectrophotometer (Optizen POP, South Korea). For ABTS radical scavenging activity, a 7 mM ABTS solution was prepared with 2.45 nM  $K_2S_2O_8$ , and the absorbance was adjusted to 0.700 at 734 nm. The extract and ABTS solution were mixed, and their volumes were made up to 2 mL. Absorbance measurements were then performed using a spectrophotometer (Zor *et al.*, 2022).

#### Organic acid analysis by LC-MS/MS

For the organic acid profile of kefir samples, acetic, citric, lactic, pyruvic, uric and tartaric acid levels were determined. For this purpose, 5 g of sample was mixed with methanol at the same ratio and centrifuged. Then, 100 µL of the supernatant was taken, 900 µL of distilled water was added, and the mixture was analysed by High Performance Liquid Chromatography (HPLC, Agilent 1220 Infinity). A Kinetex C18 column (5 µm, 100 Å, 250 × 4.6 mm, Phenomenex) was used in the analysis, and the mobile phase flow rate was adjusted to 0.8 mL/min (1 mmol/L  $H_2SO_4$  + 8 mmol/L  $Na_2SO_4$ , pH 2.8) (Terzioğlu and Bakırcı, 2024). The Limit of Detection (LOD) and Limit of Quantification (LOQ) values of the compounds analysed in the organic acid profile are given in Supplementary Table 1.

### Mineral content analysis by ICP-MS

To 150 mg of kefir sample, 10 mL of acid solution containing H<sub>2</sub>O<sub>2</sub> (2 mL, 30%) and HNO<sub>3</sub> (8 mL, 65%) was added, and the mixture was placed in the Milestone Connect Ethos Up microwave degradation system. The degradation was then carried out at 200°C T1 and 200°C T2 for 15 min each (1800 MW (w)). To obtain the stock solution, 5 mL of ultrapure water was mixed with 10 mL of the sample. The samples and the blind solution were diluted five-fold with HNO<sub>3</sub> solution (2%) and analysed using Inductively Coupled Plasma Mass Spectrometry (ICP-MS, Agilent 7800) (Terzioğlu *et al.*, 2024). The Limit of Detection (LOD) and Limit of Quantification (LOQ) values of the minerals evaluated in the analysis are given in Supplementary Table 2.

### Phenolic compound profile analysis by LC-MS/MS

For the extraction of phenolic compounds, kefir samples were homogenized at 200 rpm (30 min) and 4.5 mL acetic acid and methanol were added to 1 mL sample. The mixture was then mixed in an ultrasonic water bath and centrifuged at 4500 rpm for 10 min to obtain the extracts. For LC-HRMS analysis, an Exactive Plus Orbitrap (Thermo Fisher Scientific) high-resolution MS with a heated electrospray ionization interface was used in addition to the LC system

including a DIONEX UltiMate 3000 RS autosampler, DIONEX UltiMate 3000 RS pump and DIONEX UltiMate 3000 RS column oven. The Orbitrap-MS instrument was calibrated with positive (Pierce™ LTQ Velos ESI Positive Ion Calibration Solution) and negative calibration solutions (Pierce™ Negative Ion Calibration Solution) using an automatic syringe injector (Thermo Fisher Scientific, USA). A Phenomenex® Gemini® 3µm NX-C18 110 Å (100 mm x 2 mm) column was also used. The column oven temperature was set at 30°C, while 2% (v/v) glacial acetic acid solution was used as Solvent A and methanol was used as Solvent B (Kulaksız Günaydı and Ayar, 2022). Limit of Detection (LOD) and Limit of Quantification (LOQ) values of the analyzed phenolic compounds are given in Supplementary Table 3.

### Statistical analysis

Statistical analyses were performed using the SPSS 20.0 software package (LEAD Technologies, Inc., Chicago, USA) and the Duncan multiple range test ( $p < 0.05$ ). The data sets were further analysed by applying principal component analysis (PCA, SIMCA-P + 14.1, UMETRICS, Umea, Sweden), as well as correlation analysis, to confirm the relationships between specific parameters. The cluster analysis characterizing the heat map was performed online (<https://www.chiplot.online/>).

## Results and Discussion

### Physicochemical composition

As seen in Table 1, the total solids, ash and titratable acidity values of raw camel milk used in the production of kefir samples were determined as 12.92%, 0.77% and 0.18 % LA, respectively. Terzioğlu *et al.* (2023) determined the total solids of camel milk as 13.55%, ash content as

Table 1. Physicochemical analyses of raw camel milk.

Sample	Total Solids (%)	Ash (%)	Titratable acidity (LA %)
Raw camel milk	12.92±0.67	0.77±0.08	0.18±0.02
LA %: Lactic acid.			

Table 2. Physicochemical analyses of camel kefir samples.

Samples	Total Solids (%)	Ash (%)	Titratable acidity (LA %)
D	13.27±0.26 <sup>a</sup>	0.81±0.08 <sup>a</sup>	0.66±0.04 <sup>c</sup>
FBS	13.38±0.04 <sup>a</sup>	0.88±0.06 <sup>a</sup>	0.73±0.01 <sup>bc</sup>
FBF	13.37±0.21 <sup>a</sup>	0.89±0.02 <sup>a</sup>	0.75±0.05 <sup>b</sup>
DBS	13.43±0.10 <sup>a</sup>	0.99±0.04 <sup>a</sup>	0.85±0.02 <sup>a</sup>
DBF	13.45±0.16 <sup>a</sup>	0.97±0.03 <sup>a</sup>	0.86±0.03 <sup>a</sup>
Sign.	ns	ns	*

LA %: Lactic acid, %; Sig.: Significant; ns: Not significant; \*:  $p < 0.05$ ; \*\*:  $p < 0.01$ ; D: Control camel kefir; FBF: Camel Kefir with fresh broccoli florets; FBS: Camel Kefir with fresh broccoli stems; DBF: Camel Kefir with dried broccoli florets; DBS: Camel Kefir with dried broccoli stems.

**Table 3.** Antioxidant analyses of camel kefir samples (%).

Samples	DPPH	ABTS
D	13.63±1.54 <sup>e</sup>	37.03±3.18 <sup>e</sup>
FBS	24.49±2.05 <sup>d</sup>	45.72±2.77 <sup>d</sup>
FBF	42.88±1.45 <sup>b</sup>	63.41±3.79 <sup>b</sup>
DBS	36.97±1.96 <sup>c</sup>	56.38±0.41 <sup>c</sup>
DBF	66.89±2.47 <sup>a</sup>	77.83±1.23 <sup>a</sup>
Sign.	**	**

Sig.: Significant; \*\*: p<0.01; D: Control camel kefir; FBF: Camel Kefir with fresh broccoli florets; FBS: Camel Kefir with fresh broccoli stems; DBF: Camel Kefir with dried broccoli florets; DBS: Camel Kefir with dried broccoli stems.

0.72% and titratable acidity as 0.20 %LA. Arroum *et al.* (2025) determined the total solids of camel milk as 114.21 g/L, ash content as 8.92 g/L and the pH value as 6.77.

As seen in Table 2, statistically significant (p<0.05) differences were found between kefir samples in terms of titratable acidity analysis, while no statistically significant (p>0.05) differences were found in terms of total solids and ash analyses. The total solids, ash and titratable acidity values of the kefir samples ranged between 13.27–13.45%, 0.81–0.99% and 0.66–0.86 %LA, respectively. The addition of both fresh and dried broccoli florets and broccoli stems to kefir samples increased the total solids, ash and titratable acidity values compared to the control group samples. In addition, dried broccoli powders increased the total solids, ash and titratable acidity values more than fresh broccoli. Furthermore, both fresh and dried powdered broccoli florets were more effective on titratable acidity values than broccoli stems. This is thought to be due to the fact that the moisture in broccoli is removed by the drying process and the nutritional values increase proportionally. Campas-Baypoli *et al.* (2009) determined the moisture and ash content of fresh broccoli florets as 87% and 7.87%, respectively, and the moisture and ash content of fresh broccoli stems as 90% and 9.24%, respectively. They also reported that the moisture content of broccoli florets flour obtained after a 60°C drying and milling process was 3.7%, while the moisture content of broccoli stem flour was 3.9%. Quizhpe *et al.* (2024) revealed that the ash content of broccoli florets ranged between 7.62–8.11 g/100 g DW and the ash content of broccoli stems ranged between 10.34–12.37 g/100 g DW. Atwaa *et al.* (2022) found that total solids, ash and pH values increased with the addition of Sidr (*Ziziphus spina-christi* L.) pulp at 5%, 10% and 15% to fermented camel milk. Bertolino *et al.* (2015) reported that the addition of 3% and 6% roasted hazelnut shells to yoghurt samples increased the total solids content and decreased the ash content.

### Antioxidant activity

Statistically very significant (p<0.01) differences were found between kefir samples in terms of DPPH and ABTS analyses (Table 3). The DPPH and ABTS values in the kefir samples ranged between 13.63–66.89% and 37.03–77.83%, respectively, and it was determined that the addition of fresh and dried broccoli florets and broccoli stems to the kefir samples increased the DPPH and ABTS values compared to the control group samples. It was also found that broccoli floret powder had a greater increasing effect on DPPH and ABTS values compared to broccoli stem powder. In addition, dried broccoli powders were found to increase DPPH and ABTS values more than fresh broccoli. Réblová (2012) emphasized that antioxidant activity may decrease since some phenolic acids are very sensitive to temperature increase. On the other hand, Villaño *et al.* (2023) revealed that higher antioxidant activity was obtained in broccoli stems dried with hot air as the temperature increased. The researchers reported that the DPPH inhibition value was 22.62% in a 60°C drying process and 66.75% in an 80°C drying process. García and Raghavan (2022) reported that the DPPH and ABTS values of broccoli florets were 290.973 µg TE/g DW and 452.169 µg TE/g DW, respectively, while the DPPH and ABTS values of broccoli stems were 193.110 µg TE/g DW and 212.118 µg TE/g DW, respectively. Serna-Barrera *et al.* (2024) found that the DPPH and ABTS values of fresh broccoli stems were 2.6 mg TE/g db and 2.0 mg TE/g db, respectively. Abd El-Montaleb *et al.* (2022) reported that the antioxidant capacity of labneh cheese samples to which broccoli paste was added increased in parallel with the increase in broccoli ratio, and this increase was attributed to the phenolics, carotenoids, flavonoids, tocopherols and ascorbic acid present in broccoli. Costa *et al.* (2018) found that the addition of 5% and 10% dried artichoke and broccoli by-products to cheese samples increased ABTS values, and that broccoli by-products were more effective in enhancing the antioxidant capacity of cheese samples compared to artichoke by-products. Hong *et al.* (2021) reported that, with the addition of dried safflower leaf extracts to yoghurt samples, DPPH values ranged between 1.03–10.66% and ABTS values ranged between n.d. and 49.67%.

### Organic acid profile

Statistically very significant (p<0.01) differences were determined among kefir samples in terms of acetic acid, citric acid, lactic acid, uric acid and tartaric acid analyses, and the purivic acid value was below the Limit of Detection (LOD=0.07 mg/L) in all kefir sample groups (Table 4). The acetic acid value was determined as 7.21 mg/L in samples to which only fresh broccoli

**Table 4. Organic acid profile analyses of camel kefir samples (mg/L).**

Samples	Acetic acid	Citric acid	Lactic acid	Pyruvic acid	Uric acid	Tartaric acid
D	nd <sup>b</sup>	nd <sup>e</sup>	806.30±15.47 <sup>b</sup>	nd	1.30±0.02 <sup>c</sup>	50.06±0.03 <sup>d</sup>
FBS	7.21±0.14 <sup>a</sup>	14.59±0.20 <sup>b</sup>	765.92±5.70 <sup>c</sup>	nd	1.72±0.02 <sup>a</sup>	68.22±1.25 <sup>a</sup>
FBF	nd <sup>b</sup>	27.31±0.19 <sup>a</sup>	535.32±2.60 <sup>d</sup>	nd	1.30±0.01 <sup>c</sup>	60.72±0.05 <sup>b</sup>
DBS	nd <sup>b</sup>	nq <sup>d</sup>	821.65±13.63 <sup>b</sup>	nd	1.39±0.01 <sup>b</sup>	53.99±0.41 <sup>c</sup>
DBF	nd <sup>b</sup>	3.94±0.17 <sup>c</sup>	993.93±7.77 <sup>a</sup>	nd	1.68±0.01 <sup>a</sup>	62.29±0.81 <sup>b</sup>
Sign.	**	**	**	-	**	**

Sig.: Significant; nd: Not detected; nq: Not quantified; \*\*: p<0.01; D: Control camel kefir; FBF: Camel Kefir with fresh broccoli florets; FBS: Camel Kefir with fresh broccoli stems; DBF: Camel Kefir with dried broccoli florets; DBS: Camel Kefir with dried broccoli stems

florets powder was added. The values of citric acid, lactic acid, uric acid and tartaric acid in the kefir samples varied between nd and 27.31 mg/L, 535.32–993.93 mg/L, 1.30–1.72 mg/L and 50.06–68.22 mg/L, respectively. Among the organic acids analysed in the kefir samples, lactic acid came to the forefront as the major organic acid, as expected. It was also determined that dried broccoli powders were more effective on lactic acid content compared to fresh broccoli. In addition, the addition of broccoli florets and broccoli stems to the kefir samples increased the citric acid and tartaric acid values compared to the control group samples. When the uric acid content of the kefir samples was examined, it was determined that the addition of dried broccoli florets, dried broccoli stems and fresh broccoli stems increased the uric acid content compared to the control group. On the other hand, the addition of dried broccoli powders to the kefir samples resulted in a lower increase in citric acid content compared to fresh broccoli. This is thought to be due to the degradation of citric acid and increased transcripts of genes involved in citrate metabolism due to the effect of temperature during the drying process (Li *et al.*, 2022). The results of the present study also showed that drying negatively affected the tartaric acid content. Popp *et al.* (1996) reported that some enzymes that catalyze the breakdown of organic acids in broccoli stems become inactive with drying, while slow drying or low temperature norms can maintain the ability of enzymes to react. Durak and Yildirim (2017) determined the citric acid content of broccoli as 3.43–15.06 mg/g, lactic acid content as 0.76–1.17 mg/g and tartaric acid content as 0.29–0.95 mg/g. Liu *et al.* (2018) examined the content of lactic acid, maleic acid, malic acid and citric acid in broccoli florets and stems. They revealed that there were significant differences between broccoli by-products in terms of organic acids and that broccoli florets had high organic acid content except for malic acid. It has been reported that lactic acid bacteria are also very effective in the formation of organic acids, and that the organic acids released improve organoleptic properties by transforming

into aroma components such as alcohols, aldehydes and ketones, as well as natural aromas (Terzioğlu and Bakırcı, 2024). Marchiani *et al.* (2016) examined the lactic acid, citric acid, tartaric acid and pyruvic acid content of Toma and Cheddar cheeses to which 0.8% and 1.6% dried grape pomace was added. They found that the major organic acid in the organic acid profile of both cheeses was lactic acid, and that citric acid values decreased while tartaric acid values increased in Cheddar cheese with the addition of dried grape pomace.

#### Mineral substance content

There were statistically very significant (p<0.01) differences between kefir samples in terms of Na analysis and statistically significant (p<0.05) differences in terms of Mg, K and F analyses, while no significant (p>0.05) differences were found in terms of P, Ca and Zn analyses. In addition, the Cu value was below the Limit of Detection (LOD = 0.000063 ppm) in all kefir sample groups (Table 5). The values of Na, Mg, P, K, Ca, Fe and Zn in the kefir samples varied between 438.71–572.68 ppm, 118.70–136.61 ppm, 850.13–907.47 ppm, 1680.43–1889.28 ppm, 253.54–273.40 ppm, 0.04–0.96 ppm and 3.59–4.30 ppm, respectively. It was determined that the addition of both fresh and dried broccoli florets and broccoli stems to the kefir samples increased the Fe value compared to the control group samples. In addition, dried broccoli powders added to kefir samples increased the P and Zn contents, while fresh broccoli increased the Mg and K contents. On the other hand, the results showed that the drying process negatively affected the Na, Mg and K contents. Compared to P and Zn minerals, minerals such as Ca, Na and Mn have a lower rate of progression in the phloem, so their delivery to the developing flowers of the plant is limited; therefore, there are differences in the mineral content of broccoli florets compared to broccoli stems (Page and Feller, 2015). This is thought to cause differences in mineral content

Table 5. Mineral content analyses of camel kefir samples (ppm).

Samples	Na	Mg	P	K	Ca	Fe	Cu	Zn
D	571.08±7.57 <sup>a</sup>	124.91±1.80 <sup>b</sup>	888.60±23.24 <sup>a</sup>	1772.62±38.21 <sup>bc</sup>	273.11±3.23 <sup>a</sup>	0.04±0.03 <sup>b</sup>	nd	3.81±0.03 <sup>a</sup>
FBS	569.24±21.30 <sup>a</sup>	125.35±5.60 <sup>b</sup>	850.13±71.35 <sup>a</sup>	1827.43±79.57 <sup>ab</sup>	258.27±13.42 <sup>a</sup>	0.06±0.04 <sup>b</sup>	nd	3.59±0.21 <sup>a</sup>
FBF	572.68±6.46 <sup>a</sup>	136.61±1.18 <sup>a</sup>	873.02±10.74 <sup>a</sup>	1889.28±18.98 <sup>a</sup>	253.54±3.00 <sup>b</sup>	0.96±0.42 <sup>a</sup>	nd	4.03±0.43 <sup>a</sup>
DBS	466.11±0.15 <sup>b</sup>	122.72±0.72 <sup>b</sup>	907.47±6.92 <sup>a</sup>	1765.18±0.40 <sup>bc</sup>	273.40±1.46 <sup>a</sup>	0.40±0.11 <sup>b</sup>	nd	4.30±0.01 <sup>a</sup>
DBF	438.71±2.66 <sup>c</sup>	118.70±1.40 <sup>b</sup>	897.24±8.67 <sup>a</sup>	1680.43±7.32 <sup>c</sup>	263.80±1.83 <sup>a</sup>	0.48±0.07 <sup>ab</sup>	nd	4.24±0.03 <sup>a</sup>
Sign.	**	*	ns	*	ns	*	-	ns

Sign.: Significant; nd: Not detected; ns: Not significant; \*: p<0.05; \*\*: p<0.01; D: Control camel kefir; FBF: Camel Kefir with fresh broccoli florets; FBS: Camel Kefir with fresh broccoli stems; DBF: Camel Kefir with dried broccoli florets; DBS: Camel Kefir with dried broccoli stems.

between kefir samples supplemented with broccoli florets and stems. Liu *et al.* (2018) reported that broccoli florets and stems contained 0.39–6.43 mg/g DW of Na, 1.78–1.67 mg/g DW of Mg, 7.01–5.07 mg/g DW of P, 145–182 mg/g DW of K, 4.65–7.10 mg/g DW of Ca, 45.83–15.83 mg/g DW of Fe, 0.29–0.24 mg/g DW of Cu and 54.00–22.67 mg/g DW of Zn, respectively. In addition, the researchers determined the highest P, Fe and Zn contents in the flower part and the highest Na content in the stem part among the broccoli products they examined. Núñez-Gómez *et al.* (2022) found that dried broccoli stems contained high levels of K (47365.8 mg/kg) and Ca (4887.8 mg/kg), but low levels of Fe (15.7 mg/kg) and Zn (23.1 mg/kg).

#### Phenolic compound profile

Statistically very significant ( $p<0.01$ ) differences were determined between kefir samples in terms of syringic acid, 3,4-dihydroxybenzaldehyde (protocatechuic aldehyde), vanillin, 3,4-dihydroxyphenylacetic acid (DOPAC, homoprotocatechuic acid), sinapic acid, chlorogenic acid, quinic acid, quercetin, isoquercitrin (quercetin 3-glucoside), kuromanine (cyanidin 3-glucoside chloride), esculin hydrate, ethylgallate, and rosmarinic acid analyses, while statistically significant ( $p<0.05$ ) differences were determined in terms of 4-hydroxybenzoic acid, salicylic acid, 3-hydroxybenzoic acid (3-HBA), gentisic acid, caffeic acid and arbutin analyses (Table 6). It was observed that the addition of broccoli florets to kefir samples increased the values of 4-hydroxybenzoic acid, 3-hydroxybenzoic acid (3-HBA), vanillin, ferulic acid and kuromanine (cyanidin 3-glucoside chloride), while the addition of broccoli stems increased the values of 2,4-dihydroxybenzoic acid (beta-resorcylic acid) and ferulic acid. On the other hand, the addition of broccoli florets and broccoli stems decreased the values of benzoic acid, 3-hydroxyphenylacetic acid (3-HPA), syringic acid, gallic acid (3,4,5-trihydroxybenzoic acid),

3,4-dihydroxybenzaldehyde (protocatechuic aldehyde), vanillic acid, 3,4-dihydroxyphenylacetic acid (DOPAC, homoprotocatechuic acid), chlorogenic acid, quinic acid, vitamin C, esculin hydrate and ethylgallate compared to plain kefir samples produced from camel milk. In addition, dried broccoli powder added to kefir samples increased the 4-hydroxybenzoic acid, 3-hydroxybenzoic acid (3-HBA) and arbutin contents, while fresh broccoli increased the 2,4-dihydroxybenzoic acid (beta-resorcylic acid) and ferulic acid contents. On the other hand, the results showed that the drying process negatively affected the contents of 3-hydroxyphenylacetic acid (3-HPA), protocatechuic acid (3,4-dihydroxybenzoic acid), gentisic acid and ferulic acid.

Maillard and Berset (1995) revealed that the bond between phenolic acids and lignin can be broken with an increase in temperature, allowing insoluble phenolic compounds to be released, and that phenolic acids can be formed as a result of direct lignin degradation due to the effect of temperature. Yang *et al.* (2008) and Bolea *et al.* (2016) stated that high drying temperatures increase the degradation of flavonoids and phenolic acids. In the literature, it has been revealed that the dominant phenolic compounds in the genus *Brassica* are flavonoids (flavonols such as quercetin and kaempferol, and catechin) and phenolic acids, including hydroxybenzoic acids such as syringic acid, gallic acid, vanillic acid, protocatechuic acid and salicylic acid, as well as hydroxycinnamic acids such as coumaric acid, caffeic acid, chlorogenic acid, sinapic acid and ferulic acid (Schmidt *et al.*, 2010; Cartea *et al.*, 2011; Kumar, 2017). In broccoli, the main phenolic acids are ferulic acid, gallic acid, chlorogenic acid, caffeic acid and sinapic acid (Liu *et al.*, 2018; Borja-Martínez *et al.*, 2020). García and Raghavan (2022) reported that ferulic acid was the most predominant phenolic compound in both broccoli florets and broccoli stems, and that broccoli florets were richer in gallic acid, sinapic acid and vanillic acid than broccoli stems. In addition, Bhandari

Table 6. Phenolic content profile analyses of camel kefir samples (ng/mL).

Samples	D	FBS	FBF	DBS	DBF	Sign.
Benzoic acid	132403.21±1890.51 <sup>a</sup>	55124.08±63796.54 <sup>a</sup>	100521.16±251.22 <sup>a</sup>	99392.72±656.15 <sup>a</sup>	105266.00±106.07 <sup>a</sup>	ns
4-Hydroxybenzoic acid	203.18±11.81 <sup>cd</sup>	86.35±98.04 <sup>d</sup>	746.04±9.23 <sup>a</sup>	366.01±168.20 <sup>bc</sup>	492.87±56.70 <sup>b</sup>	*
Salicylic acid	843.37±26.86 <sup>a</sup>	228.63±259.59 <sup>b</sup>	649.88±21.35 <sup>a</sup>	730.68±44.82 <sup>a</sup>	860.72±11.85 <sup>a</sup>	*
3-Hydroxybenzoic acid (3-HBA)	331.47±67.73 <sup>bc</sup>	135.23±148.56 <sup>c</sup>	746.24±8.93 <sup>a</sup>	364.67±166.45 <sup>bc</sup>	497.06±50.20 <sup>ab</sup>	*
3-Hydroxyphenylacetic acid (3-HPA)	672.48±25.14 <sup>a</sup>	338.79±404.02 <sup>a</sup>	390.51±552.26 <sup>a</sup>	290.11±300.84 <sup>a</sup>	nd <sup>a</sup>	ns
Syringic acid	28.22±4.26 <sup>a</sup>	nd <sup>b</sup>	nd <sup>b</sup>	1.12±1.58 <sup>b</sup>	nd <sup>b</sup>	**
Gallic acid (3,4,5-trihydroxybenzoic acid)	20.59±29.11 <sup>a</sup>	nd <sup>a</sup>	nd <sup>c</sup>	nd <sup>a</sup>	nd <sup>a</sup>	ns
Protocatechuic acid (3,4-dihydroxybenzoic acid)	247.90±66.95 <sup>a</sup>	189.49±219.88 <sup>a</sup>	351.24±93.04 <sup>a</sup>	60.14±15.95 <sup>a</sup>	nd <sup>a</sup>	ns
3,4-dihydroxybenzaldehyde (Protocatechuic aldehyde)	197.12±10.06 <sup>a</sup>	nd <sup>b</sup>	nd <sup>b</sup>	nd <sup>b</sup>	nd <sup>b</sup>	**
2,4-dihydroxybenzoic acid (Beta-resoroylic acid)	31.12±4.68 <sup>a</sup>	64.28±70.36 <sup>a</sup>	51.16±2.74 <sup>a</sup>	42.25±5.70 <sup>a</sup>	nd <sup>a</sup>	ns
Vanillic acid	6951.41±9830.77 <sup>a</sup>	392.63±459.57 <sup>a</sup>	576.63±82.14 <sup>a</sup>	nd <sup>a</sup>	678.65±1.22 <sup>a</sup>	ns
Vanillin	nd <sup>c</sup>	29.31±33.93 <sup>bc</sup>	207.67±56.08 <sup>a</sup>	nd <sup>c</sup>	83.80±6.92 <sup>b</sup>	**
Gentisic acid	nd <sup>b</sup>	45.65±51.54 <sup>b</sup>	108.28±13.80 <sup>a</sup>	nd <sup>b</sup>	nd <sup>b</sup>	*
3,4-dihydroxyphenylacetic acid (DOPAC, Homoprotocatechuic acid)	14276.69±422.87 <sup>a</sup>	401.31±469.87 <sup>bc</sup>	585.56±86.22 <sup>bc</sup>	nd <sup>c</sup>	789.58±30.00 <sup>b</sup>	**
Coumaric acid (trans-3-hydroxycinnamic acid)	46.09±4.91 <sup>a</sup>	26.21±31.98 <sup>a</sup>	21.23±0.36 <sup>a</sup>	50.53±7.92 <sup>a</sup>	nd <sup>a</sup>	ns
Caffeic acid	143.87±11.40 <sup>a</sup>	45.69±52.76 <sup>b</sup>	156.54±17.31 <sup>a</sup>	67.42±14.76 <sup>b</sup>	58.61±11.52 <sup>b</sup>	*
Ferulic acid	nd <sup>b</sup>	207.17±254.17 <sup>ab</sup>	432.86±8.21 <sup>a</sup>	77.24±5.08 <sup>b</sup>	135.17±1.88 <sup>ab</sup>	ns
Sinapic acid	238.82±7.01 <sup>a</sup>	nd <sup>c</sup>	176.51±36.88 <sup>b</sup>	nd <sup>c</sup>	nd <sup>c</sup>	**
Chlorogenic acid	83.33±4.83 <sup>a</sup>	nd <sup>c</sup>	29.35±1.56 <sup>b</sup>	nd <sup>c</sup>	nd <sup>c</sup>	**
Quinic acid	309.29±15.39 <sup>a</sup>	nd <sup>c</sup>	171.51±9.95 <sup>b</sup>	nd <sup>c</sup>	nd <sup>c</sup>	**
C vitamin	986.94±14.98 <sup>a</sup>	378.24±422.51 <sup>a</sup>	359.56±7.01 <sup>a</sup>	369.62±50.66 <sup>a</sup>	375.79±38.69 <sup>a</sup>	ns
Quercetin	nd <sup>b</sup>	nd <sup>b</sup>	65.42±0.52 <sup>a</sup>	nd <sup>b</sup>	nd <sup>b</sup>	**
Isoquercitrin (Quercetin 3-glucoside)	nd <sup>b</sup>	nd <sup>b</sup>	45.06±6.64 <sup>a</sup>	nd <sup>b</sup>	nd <sup>b</sup>	**
Kuromanine (Cyanidin 3-glucoside chloride)	nd <sup>c</sup>	nd <sup>c</sup>	1704.75±48.42 <sup>a</sup>	nd <sup>c</sup>	813.21±43.00 <sup>b</sup>	**
Esculin hydrate	190.60±5.71 <sup>a</sup>	nd <sup>b</sup>	nd <sup>b</sup>	nd <sup>b</sup>	nd <sup>b</sup>	**
Arbutin	nd <sup>b</sup>	179.23±209.41 <sup>b</sup>	nd <sup>b</sup>	206.33±14.30 <sup>b</sup>	473.53±3.98 <sup>a</sup>	*
Ethylgallate	28.67±4.88 <sup>a</sup>	nd <sup>b</sup>	nd <sup>b</sup>	nd <sup>b</sup>	nd <sup>b</sup>	**
Rosmarinic acid	nd <sup>b</sup>	nd <sup>b</sup>	nd <sup>b</sup>	23.74±0.29 <sup>a</sup>	nd <sup>b</sup>	**

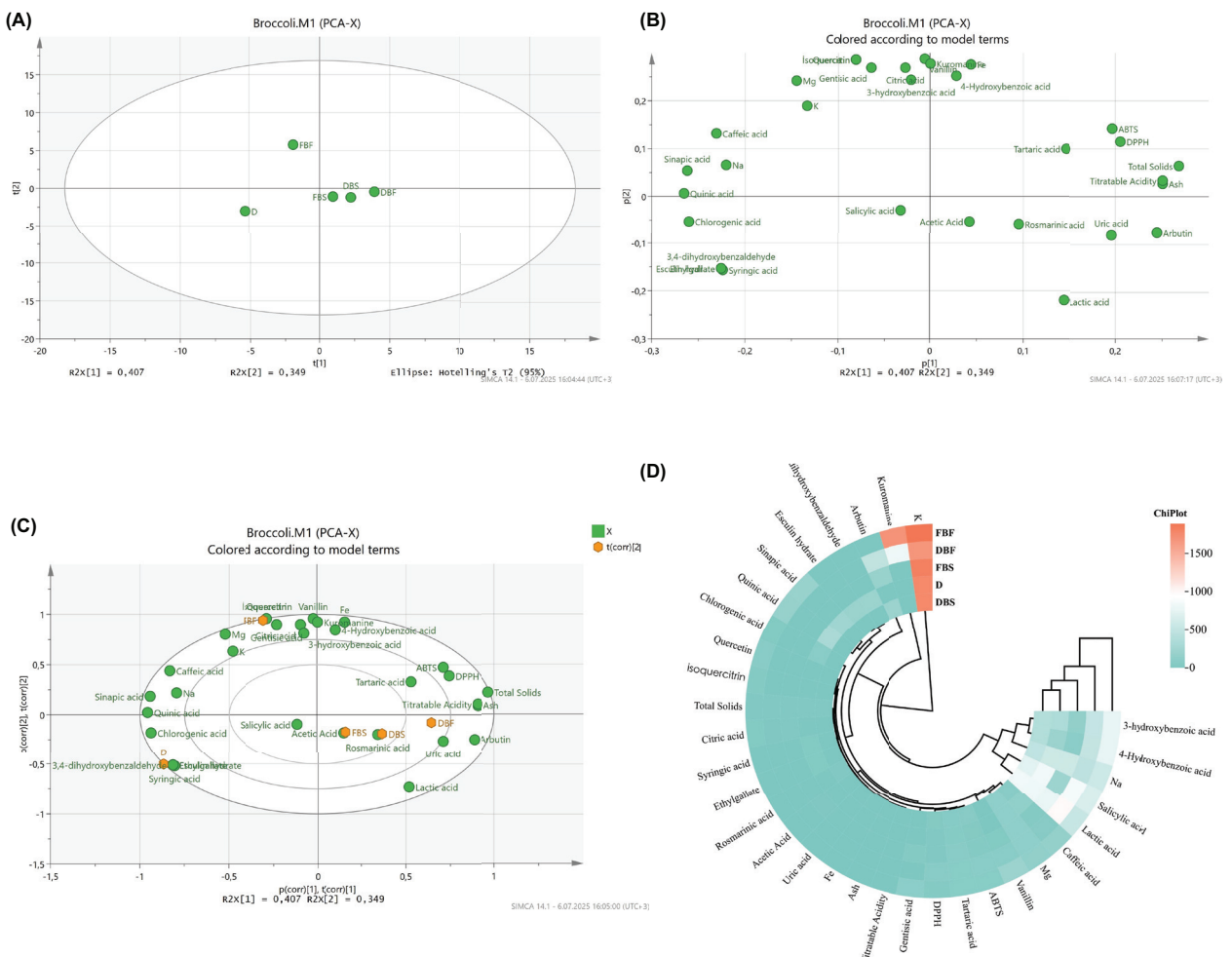
Fig.: Significant; nd: Not detected; ns: Not significant; \*, p<0.05; \*\*, p<0.01; D: Control camel kefir, FBF: Camel Kefir with fresh broccoli florets; FBS: Camel Kefir with fresh broccoli stems; DBF: Camel Kefir with dried broccoli florets; DBS: Camel Kefir with dried broccoli stems.

and Kwak (2014) emphasised that broccoli stems have a richer vitamin C content compared to broccoli florets. Furthermore, some favorable results observed in the phenolic compound profile of samples with added broccoli, compared to plain kefir samples produced from camel milk, are thought to be due to the various phenolic acids and flavonoids present in broccoli, as well as the fact that the microorganisms used in kefir production during the fermentation process break down the glucosinolates contained in broccoli and convert them into phenolic compounds (Shashirekha *et al.*, 2015; Krupa-Kozak *et al.*, 2021).

*Principal component analysis*

The PCA plots of the control camel kefir and camel kefir samples with the addition of fresh and dried broccoli florets and stems are presented in Figure 2. In addition,

Figure 2-D shows the cluster analysis of the heat map illustrating the relationship between the samples and the analyses. According to the PCA results of the physicochemical and biochemical properties of the kefir samples, the first two main components (40.7% and 34.9%) accounted for 75.6% of the total variance. As can be seen from Figures 2-A and 2-D, the samples were essentially divided into two groups: kefir samples with added fresh broccoli florets and the other samples. However, the samples with the addition of dried broccoli florets, the samples with the addition of fresh and dried broccoli stems, and the control samples were further subdivided into subgroups. This emphasizes the differences between the samples and shows that both the drying process and the use of different parts of broccoli affected the results. In Figure 2-B, it was observed that total solids, ash, titratable acidity, DPPH, ABTS, lactic acid, tartaric acid, uric acid, Fe, kuromanine, 4-hydroxybenzoic acid, arbutin and rosmarinic acid values were clustered on the right side of



**Figure 2.** PCA and the cluster analysis of heat map characterizing. (A) Score scatter, (B) Loading Scatter Plot, (C) Biplot, (D) The cluster analysis of heat map characterizing.

the plot, while the other parameters were clustered on the left side. However, when Figure 2-C is analysed, the clustering of 4-hydroxybenzoic acid, 3-hydroxybenzoic acid (3-HBA), isoquercitrin, gentisic acid, vanillin, kuromanine, citric acid, Mg, K and Fe in the sample with fresh broccoli florets (FBF) demonstrates its superiority over the other samples in terms of these parameters. Similarly, it was observed that the control group sample (D) was superior in terms of 3,4-dihydroxybenzaldehyde, esculin hydrate, ethylgallate, syringic acid, quinic acid, sinapic acid and chlorogenic acid, while the samples with dried broccoli florets (DBF) were superior in terms of total solids, titratable acidity, DPPH, ABTS and arbutin.

## Conclusion

In this study, camel milk kefir was produced, and fresh and dried broccoli florets and broccoli stems were added to the samples in order to ensure that camel milk, which has an important place in terms of nutrition and health, reaches consumers of all ages, to improve its functional properties, to present a new product, and to prevent environmental pollution by conducting a waste evaluation study. In the present study, it was determined that kefir produced from camel milk have significant potential in terms of bioactive compounds and antioxidant activity, that camel milk should not be limited to traditional uses, and that it is a suitable product that can be integrated with new ingredients such as broccoli in line with consumer demands and needs. In addition, it was determined that the discarded stems of broccoli are highly suitable for the production of nutraceutical and functional products, possess certain superior properties compared to the broccoli florets that are currently consumed, and that many properties expected to be negatively affected by the drying process are, in fact, positively improved. Therefore, the reuse of broccoli stems, which are considered waste, either fresh or dried, in an integrated manner with camel kefir represents a significant advancement in terms of economic, health, environmental and social perspectives.

## Conflicts of Interest

The authors declare no conflict of interest.

## Funding

This research received no external funding.

## References

- Abd El-Montaleb, H.S., Abbas, K.A.E., Mwaheb, M.A., & Hamdy, S.M. (2022). Production and characteristic quality of probiotic Labneh cheese supplemented with broccoli florets. *British Food Journal*, 124(11), 3666–3679. <https://doi.org/10.1108/BJFJ-05-2021-0554>
- Abdelazez, A., Abd-elmotaal, H., & Abady, G. (2024). Exploring the potential of camel milk as a functional food: Physicochemical characteristics, bioactive components, innovative therapeutic applications, and development opportunities analysis. *Food Materials Research*, 4, e031. <https://doi.org/10.48130/fmr-0024-0020>
- Ait El Alia, O., Zine-Eddine, Y., Chaji, S., Boukrouh, S., Boutoial, K., & Faye, B. (2025). Global camel milk industry: A comprehensive overview of production, consumption trends, market evolution, and value chain efficiency. *Small Ruminant Research*, 243, 107441. <https://doi.org/10.1016/j.smallrumres.2025.107441>
- Al-Ayadhi, L.Y., Halepoto, D.M., Al-Dress, A.M., Mitwali, Y., & Zainah, R. (2015). Behavioral benefits of camel milk in subjects with autism spectrum disorder. *Journal of the College of Physicians and Surgeons Pakistan*, 25(11), 819–823.
- Ali, W., Akyol, E., Ceyhan, A., Dilawar, S., Firdous, A., Zia ul Qasim, M., & Ahmad, M.M. (2019). Milk production and composition in camel and its beneficial uses: A review. *Turkish Journal of Agriculture – Food Science and Technology*, 7(12), 2142–2147. <https://doi.org/10.24925/turjaf.v7i12.2142-2147.2905>
- Almasri, R.S., Bedir, A.S., Ranneh, Y.K., El-Tarabily, K.A., & Al Raish, S.M. (2024). Benefits of camel milk over cow and goat milk for infant and adult health in fighting chronic diseases: A review. *Nutrients*, 16(22), 3848. <https://doi.org/10.3390/nu16223848>
- Anand, S., & Barua, M.K. (2022). Modeling the key factors leading to post-harvest loss and waste of fruits and vegetables in the agri-fresh produce supply chain. *Computers and Electronics in Agriculture*, 198, 106936. <https://doi.org/10.1016/j.compag.2022.106936>
- Aral, S., & Beşe, A.V. (2016). Convective drying of hawthorn fruit (*Crataegus* spp.): Effect of experimental parameters on drying kinetics, color, shrinkage, and rehydration capacity. *Food Chemistry*, 210, 577–584. <https://doi.org/10.1016/j.foodchem.2016.04.128>
- Arroum, S., Sboui, A., Fguiri, I., Dbara, M., Ayeb, N., Hammadi, M., & Khorchani, T. (2025). Influence of kefir grain concentration on the nutritional, microbiological, and sensory properties of camel milk kefir and characterisation of some technological properties. *Fermentation*, 11(4), 170. <https://doi.org/10.3390/fermentation11040170>
- Atwaa, E.S.H., Shahein, M.R., Alrashdi, B.M., Hassan, M.A.A., Alblihed, M.A., Dahran, N., Ali, F.A.Z., & Elmahallawy, E.K. (2022). Effects of fermented camel milk supplemented with Sidr fruit (*Ziziphus spina-christi* L.) pulp on hyperglycaemia in streptozotocin-induced diabetic rats. *Fermentation*, 8(6), 269. <https://doi.org/10.3390/fermentation8060269>
- Baniasadi, M., Azizkhani, M., Saris, P.E.J., & Tooryan, F. (2022). Comparative antioxidant potential of kefir and yoghurt of bovine and non-bovine origins. *Journal of Food Science and Technology*, 59(4), 1307–1316. <https://doi.org/10.1007/s13197-021-05139-9>

- Barazi, Ü., & Arslan, S. (2024). Enhancement of kefir functionality by adding black elderberry and evaluation of its quality during storage. *Food Science and Nutrition*, 12(11), 9325–9339. <https://doi.org/10.1002/fsn3.4481>
- Bas-Bellver, C., Barrera, C., & Seguí, L. (2024). Impact of thermo-physical and biological pretreatments on antioxidant properties and phenolic profile of broccoli stem products. *Foods*, 13(22), 3585. <https://doi.org/10.3390/foods13223585>
- Bertolino, M., Belviso, S., Dal Bello, B., Ghirardello, D., Giordano, M., Rolle, L., Gerbi, V., & Zeppa, G. (2015). Influence of the addition of different hazelnut skins on the physicochemical, antioxidant, polyphenol and sensory properties of yoghurt. *LWT – Food Science and Technology*, 63(2), 1145–1154. <https://doi.org/10.1016/j.lwt.2015.03.113>
- Bhandari, S.R., & Kwak, J.-H. (2014). Seasonal variation in phytochemicals and antioxidant activities in different tissues of various broccoli cultivars. *African Journal of Biotechnology*, 13(4), 604–615. <https://doi.org/10.5897/AJB2013.13432>
- Bolea, C., Turturică, M., Stănciuc, N., & Vizireanu, C. (2016). Thermal degradation kinetics of bioactive compounds from black rice flour (*Oryza sativa* L.) extracts. *Journal of Cereal Science*, 71, 160–166. <https://doi.org/10.1016/j.jcs.2016.08.010>
- Borja-Martínez, M., Lozano-Sánchez, J., Borrás-Linares, I., Pedreño, M.A., & Sabater-Jara, A.B. (2020). Revalorization of broccoli by-products for cosmetic uses using supercritical fluid extraction. *Antioxidants*, 9(12), 1195. <https://doi.org/10.3390/antiox9121195>
- Campas-Baypoli, O.N., Sánchez-Machado, D.I., Bueno-Solano, C., Núñez-Gastélum, J.A., Reyes-Moreno, C., & López-Cervantes, J. (2009). Biochemical composition and physicochemical properties of broccoli flours. *International Journal of Food Sciences and Nutrition*, 60(S4), 163–173. <https://doi.org/10.1080/09637480802702015>
- Cartea, M.E., Francisco, M., Soengas, P., & Velasco, P. (2011). Phenolic compounds in *Brassica* vegetables. *Molecules*, 16(1), 251–280. <https://doi.org/10.3390/molecules16010251>
- Ciniviz, M., & Yildiz, H. (2020). Determination of phenolic acid profiles by HPLC in lacto-fermented fruits and vegetables (pickle): Effect of pulp and juice portions. *Journal of Food Processing and Preservation*, 44(7), e14542. <https://doi.org/10.1111/jfpp.14542>
- Clarke, J.D., Dashwood, R.H., & Ho, E. (2008). Multi-targeted prevention of cancer by sulforaphane. *Cancer Letters*, 269(2), 291–304. <https://doi.org/10.1016/j.canlet.2008.04.018>
- 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>
- Dufoo-Hurtado, M.D., Vazquez-Barrios, M.E., Ramirez-Gonzalez, E., Vazquez-Celestino, D., Rivera-Pastrana, D.M., & Mercado-Silva, E. (2018). Nutritional, nutraceutical and functional properties of flours obtained from broccoli waste material dried at different temperatures. *Acta Horticulturae*, 1292, 137–144. <https://doi.org/10.17660/ActaHortic.2020.1292.18>
- Durak, E., & Yıldırım, M. (2017). Yield and quality compounds of broccoli (*Brassica oleracea* L. cv. Beaumont) as affected by different irrigation levels. *ÇOMÜ Ziraat Fakültesi Dergisi*, 5(1), 13–20.
- García, S.L.R., & Raghavan, V. (2022). Microwave-assisted extraction of phenolic compounds from broccoli (*Brassica oleracea*) stems, leaves, and florets: Optimization, characterisation, and comparison with maceration extraction. *Recent Progress in Nutrition*, 2(2), 1–23. <https://doi.org/10.21926/rpn.2202011>
- Gudiño, I., Casquete, R., Martín, A., Wu, Y., & Benito, M.J. (2024). Comprehensive analysis of bioactive compounds, functional properties, and applications of broccoli by-products. *Foods*, 13(23), 3918. <https://doi.org/10.3390/foods13233918>
- Gül, L.B., Bekbay, S., Akgün, A., & Gül, O. (2023). Effect of oleaster (*Elaeagnus angustifolia* L.) flour addition combined with high-pressure homogenization on the acidification kinetics, physicochemical, functional, and rheological properties of kefir. *Food Science and Nutrition*, 11(9), 5325–5337. <https://doi.org/10.1002/fsn3.3491>
- Ho, T.M., Zou, Z., & Bansal, N. (2022). Camel milk: A review of its nutritional value, heat stability, and potential food products. *Food Research International*, 153, 110870. <https://doi.org/10.1016/j.foodres.2021.110870>
- Hong, H., Lim, J.M., Kothari, D., Kwon, S.H., Kwon, H.C., Han, S.G., & Kim, S.K. (2021). Antioxidant properties and diet-related  $\alpha$ -glucosidase and lipase inhibitory activities of yoghurt supplemented with safflower (*Carthamus tinctorius* L.) petal extract. *Food Science of Animal Resources*, 41(1), 122–134. <https://doi.org/10.5851/kosfa.2020.e88>
- Hwang, J.-H., & Lim, S.-B. (2015). Antioxidant and anticancer activities of broccoli by-products from different cultivars and maturity stages at harvest. *Preventive Nutrition and Food Science*, 20(1), 8–14. <https://doi.org/10.3746/pnf.2015.20.1.8>
- Karwacka, M., Cieurzyńska, A., Lenart, A., & Janowicz, M. (2020). Sustainable development in the agri-food sector in terms of the carbon footprint: A review. *Sustainability*, 12(16), 6463. <https://doi.org/10.3390/su12166463>
- Krupa-Kozak, U., Drabińska, N., Bączek, N., Šimková, K., Starowicz, M., & Jeliński, T. (2021). Application of broccoli leaf powder in gluten-free bread: An innovative approach to improve its bioactive potential and technological quality. *Foods*, 10(4), 819. <https://doi.org/10.3390/foods10040819>
- Kulaksız Günaydı, Z.E., & Ayar, A. (2022). Phenolic compounds, amino acid profiles, and antibacterial properties of kefir prepared using freeze-dried *Arbutus unedo* L. and *Tamarindus indica* L. fruits and sweetened with stevia, monk fruit sweetener, and aspartame. *Journal of Food Processing and Preservation*, 46, e16767. <https://doi.org/10.1111/jfpp.16767>
- Kumar, B.R. (2017). Application of HPLC and ESI-MS techniques in the analysis of phenolic acids and flavonoids from green leafy vegetables (GLVs). *Journal of Pharmaceutical Analysis*, 7(6), 349–364. <https://doi.org/10.1016/j.jpha.2017.06.005>

- Kumar, D., Verma, A.K., Chatli, M.K., Singh, R., Kumar, P., Mehta, N., & Malav, O.P. (2016). Camel milk: Alternative milk for human consumption and its health benefits. *Nutrition and Food Science*, 46(2), 217–227. <https://doi.org/10.1108/NFS-07-2015-0085>
- Kumar, H., Bhardwaj, K., Cruz-Martins, N., Sharma, R., Siddiqui, S.A., Dhanjal, D.S., Singh, R., Chopra, C., Dantas, A., Verma, R., Dosoky, N.S., & Kumar, D. (2022). Phyto-enrichment of yoghurt to control hypercholesterolaemia: A functional approach. *Molecules*, 27(11), 3479. <https://doi.org/10.3390/molecules27113479>
- Li, S.J., Liu, S.C., Lin, X.H., Grierson, D., Yin, X.R., & Chen, K.S. (2022). Citrus heat shock transcription factor CitHsfA7-mediated citric acid degradation in response to heat stress. *Plant, Cell & Environment*, 45(1), 95–104. <https://doi.org/10.1111/pce.14207>
- Li, Y., & Zhang, T. (2013). Targeting cancer stem cells with sulforaphane, a dietary component from broccoli and broccoli sprouts. *Future Oncology*, 9(8), 1097–1103. <https://doi.org/10.2217/fon.13.108>
- Liu, M., Zhang, L., Ser, S.L., Cumming, J.R., & Ku, K.-M. (2018). Comparative phytonutrient analysis of broccoli by-products: The potentials for broccoli by-product utilization. *Molecules*, 23(4), 900. <https://doi.org/10.3390/molecules23040900>
- Maillard, M.N., & Berset, C. (1995). Evolution of antioxidant activity during kilning: Role of insoluble bound phenolic acids of barley and malt. *Journal of Agricultural and Food Chemistry*, 43(7), 1789–1793.
- Marchiani, R., Bertolino, M., Ghirardello, D., McSweeney, P.L.H., & Zeppa, G. (2016). Physicochemical and nutritional qualities of grape pomace powder-fortified semi-hard cheeses. *Journal of Food Science and Technology*, 53(3), 1585–1596. <https://doi.org/10.1007/s13197-015-2105-8>
- Muelas, R., Romero, G., Díaz, J.R., Monllor, P., Fernández-López, J., Viuda-Martos, M., Cano-Lamadrid, M., & Sendra, E. (2022). Quality and functional parameters of fermented milk obtained from goat milk fed with broccoli and artichoke plant by-products. *Foods*, 11(17), 2601. <https://doi.org/10.3390/foods11172601>
- Muller, S., Jardine, W.G., Evans, B.W., Vietor, R.J., Snape, C.E., & Jarvis, M.C. (2003). Cell wall composition of vascular and parenchyma tissues in broccoli stems. *Journal of the Science of Food and Agriculture*, 83(13), 1289–1292. <https://doi.org/10.1002/jsfa.144>
- Núñez-Gómez, V., González-Barrio, R., Baenas, N., Moreno, D.A., & Periago, M.J. (2022). Dietary-fibre-rich fractions isolated from broccoli stalks as a potential functional ingredient with phenolic compounds and glucosinolates. *International Journal of Molecular Sciences*, 23(21), 13309. <https://doi.org/10.3390/ijms232113309>
- Page, V., & Feller, U. (2015). Heavy metals in crop plants: Transport and redistribution processes on the whole plant level. *Agronomy*, 5(3), 447–463. <https://doi.org/10.3390/agronomy5030447>
- Popp, M., Lied, W., Meyer, A.J., Richter, A., Schiller, P., & Schwitte, H. (1996). Sample preservation for determination of organic compounds: Microwave versus freeze-drying. *Journal of Experimental Botany*, 47(10), 1469–1473. <https://academic.oup.com/jxb/article/47/10/1469/565939>
- Quizhpe, J., Ayuso, P., Rosell, M.D.Á., Peñalver, R., & Nieto, G. (2024). *Brassica oleracea* var. *italica* and their by-products as source of bioactive compounds and food applications in bakery products. *Foods*, 13(21), 3513. <https://doi.org/10.3390/foods13213513>
- Rajković, M.B., Minić, D.P., Milinčić, D., & Zdravković, M. (2020). Circular economy in food industry. *Zaštita Materijala*, 61(3), 229–250. <https://doi.org/10.5937/zasmat2003229R6>
- Réblová, Z. (2012). Effect of temperature on the antioxidant activity of phenolic acids. *Czech Journal of Food Sciences*, 30(2), 171–175. <https://doi.org/10.17221/57/2011-CJFS>
- Sakandar, H.A., Ahmad, S., Perveen, R., Aslam, H.K.W., Shakeel, A., Sadiq, F.A., & Imran, M. (2018). Camel milk and its allied health claims: A review. *Progress in Nutrition*, 20(Supplement 1), 15–29. <https://doi.org/10.23751/pn.v20i1-S.5318>
- Schmidt, S., Zietz, M., Schreiner, M., Rohn, S., Kroh, L.W., & Krumbein, A. (2010). Genotypic and climatic influences on the concentration and composition of flavonoids in kale (*Brassica oleracea* var. *sabellica*). *Food Chemistry*, 119(4), 1293–1299. <https://doi.org/10.1016/j.foodchem.2009.09.004>
- Serna-Barrera, M.A., Bas-Bellver, C., Seguí, L., Betoret, N., & Barrera, C. (2024). Exploring fermentation with lactic acid bacteria as a pretreatment for enhancing antioxidant potential in broccoli stem powders. *AIMS Microbiology*, 10(2), 255–272. <https://doi.org/10.3934/microbiol.2024013>
- Sharma, P., Gaur, V.K., Sirohi, R., Varjani, S., Kim, S.H., & Wong, J.W. (2021). Sustainable processing of food waste for production of bio-based products for circular bioeconomy. *Bioresource Technology*, 325, 124684. <https://doi.org/10.1016/j.biortech.2021.124684>
- Shashirekha, M.N., Mallikarjuna, S.E., & Rajarathnam, S. (2015). Status of bioactive compounds in foods, with focus on fruits and vegetables. *Critical Reviews in Food Science and Nutrition*, 55(10), 1324–1339. <https://doi.org/10.1080/10408398.2012.692736>
- Tan, C.H., Hii, C.L., Borompichaichartkul, C., Phumsombat, P., Kong, I., & Pui, L.P. (2022). Valorization of fruits, vegetables, and their by-products: Drying and bio-drying. *Drying Technology*, 40(8), 1514–1538. <https://doi.org/10.1080/07373937.2022.2068570>
- Terzioğlu, M.E., & Bakırcı, İ. (2024). Comparison of amino acid profile, ACE inhibitory activity, and organic acid profile of cow and goat yogurts produced with *Lactobacillus acidophilus* LA-5, *Bifidobacterium animalis* subsp. *lactis* BB-12, and classical yogurt culture. *Probiotics and Antimicrobial Proteins*, 16(5), 1566–1582. <https://doi.org/10.1007/s12602-023-10123-0>
- Terzioğlu, M.E., Edebali, E., & Bakırcı, İ. (2024). Investigation of the elemental contents, functional and nutraceutical properties of kefir enriched with *Spirulina platensis*, an eco-friendly and alternative protein source. *Biological Trace Element Research*, 202(6), 2878–2890. <https://doi.org/10.1007/s12011-023-03844-4>
- Terzioğlu, M.E., Bakırcı, İ., Oz, E., Brennan, C.S., Huppertz, T., Amarowicz, R., Khan, M.R., Elobeid, T., Aadil, R.M., & Oz, F. (2023). Comparison of camel, buffalo, cow, goat, and sheep

- yoghurts in terms of various physicochemical, biochemical, textural and rheological properties. *International Dairy Journal*, 146, 105749. <https://doi.org/10.1016/j.idairyj.2023.105749>
- Thomas, M., Badr, A., Desjardins, Y., Gosselin, A., & Angers, P. (2018). Characterization of industrial broccoli discards (*Brassica oleracea* var. *italica*) for their glucosinolate, polyphenol and flavonoid contents using UPLC MS/MS and spectrophotometric methods. *Food Chemistry*, 245, 1204–1211. <https://doi.org/10.1016/j.foodchem.2017.11.021>
- Villaño, D., Fernández-Pan, I., Arozarena, Í., Ibañez, F.C., Vírveda, P., & Beriain, M.J. (2023). Revalorisation of broccoli crop surpluses and field residues: Novel ingredients for food industry uses. *European Food Research and Technology*, 249(12), 3227–3237. <https://doi.org/10.1007/s00217-023-04362-2>
- Xu, Y., Xiao, Y., Lagnika, C., Song, J., Li, D., Liu, C., Jiang, N., Zhang, M., & Duan, X. (2020). A comparative study of drying methods on physical characteristics, nutritional properties and antioxidant capacity of broccoli. *Drying Technology*, 38(10), 1378–1388. <https://doi.org/10.1080/07373937.2019.1656642>
- Yang, Z., Han, Y., Gu, Z., Fan, G., & Chen, Z. (2008). Thermal degradation kinetics of aqueous anthocyanins and visual color of purple corn (*Zea mays* L.) cob. *Innovative Food Science & Emerging Technologies*, 9(3), 341–347. <https://doi.org/10.1016/j.ifset.2007.09.001>
- Zhang, J., Cao, J., Pei, Z., Wei, P., Xiang, D., Cao, X., Shen, X., & Li, C. (2019). Volatile flavour components and the mechanisms underlying their production in golden pompano (*Trachinotus blochii*) fillets subjected to different drying methods: A comparative study using an electronic nose, an electronic tongue and SDE-GC-MS. *Food Research International*, 123, 217–225. <https://doi.org/10.1016/j.foodres.2019.04.069>
- Zhao, Y., Zhang, W., Yang, H., Xu, Z., Wang, X., Zhang, Z., & Deng, J. (2025). Effects of drying methods on phytochemicals and antioxidant activity of broccoli by-products. *Food Research International*, 208, 116284. <https://doi.org/10.1016/j.foodres.2025.116284>
- Zor, M., Sengul, M., Karakütük, İ.A., & Odunkiran, A. (2022). Changes caused by different cooking methods in some physicochemical properties, antioxidant activity, and mineral composition of various vegetables. *Journal of Food Processing and Preservation*, 46(11), e16960. <https://doi.org/10.1111/jfpp.16960>