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Physicochemical and Microbiological Properties of Different Kayseri Pastirma Types

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Abstract

In this study, a total of 20 pastirma samples were collected from the Kayseri local market, and their physicochemical (moisture, pH) and microbiological (lactic acid bacteria, total yeast-mold, total mesophilic aerobic bacteria) properties were investigated. Moisture and pH values of samples ranged from 34.77 to 57.61% and 5.81 to 6.22, respectively. While LAB counts of samples ranged from <2 to 5.61 log CFU/g, TMAB counts were found between 3.89 and 8.60 log CFU/g. Yeast counts were highest in the P9 sample, while mold counts were highest in the P11 sample. In conclusion, these pastirma samples exhibited significant variability in the physicochemical and microbiological properties due to differences in sample type and production conditions. Furthermore, the use of different culture media led to variations in yeast and mold counts, highlighting the critical role of media selection in accurately assessing the microbiological characteristics of pastirma.

Keywords: Pastirma, Kayseri, Yeast, Mold, Lactic acid bacteria.

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1. Introduction

Pastirma is one of the most popular dry-cured meat products in Turkiye, widely appreciated for its distinctive flavor. It is a raw cured meat product made from specific cuts of beef or water buffalo carcasses. Sixteen or more types of pastirma can be produced from suitable cuts obtained from a single carcass. The different types of pastirma are named according to the location of the muscles or muscle groups used as raw materials, such as ‘şekerpare’, ‘kuşgömü’, ‘bohça’, ‘kürek’, and ‘sırt’ (Figure 1). Consequently, there are differences in texture and quality characteristics among the different types of pastirma (Gökalp et al., 1994, Ozturk, 2015).

During the production of pastirma, low water activity values are observed due to the drying and salting processes. Pastirma is classified as a semi-moist food and does not involve heating or smoking during production (Leistner, 1988). The çemen paste imparts a pleasant flavor and aroma to the product. Additionally, the çemen paste helps protect pastirma against microorganisms (Yetim et al., 2006).

Pastirma is traditionally processed under natural conditions determined by air temperature, relative humidity, climate, and weather conditions. The period known as "Pastirma Summer", which includes September, October, and November, is preferred for traditional production (Gökalp et al., 1994). The first stage of pastirma production is dry curing. In this stage, salt is used at levels of 8-10%. Several incisions are made on the meat to facilitate the penetration of the curing mixture. The meat strips are coated with the curing mixture. Nitrate is commonly used as a curing agent (Tekinşen & Doğruer, 2000). Additionally, nitrite or nitrite-nitrate mixtures can be employed as curing agents. Sucrose and glucose may also be added to the curing mixture (Aksu & Kaya, 2002). The salted meat strips are arranged in stacks about 1 meter high, piled consecutively, and left for one to two days (Gökalp et al., 1994).

Lactic acid bacteria and catalase-positive cocci (*Micrococcus*/*Staphylococcus*) are two significant groups of microorganisms used in the production of pastirma. Catalase-positive cocci exhibit nitrate reductase activity in addition to catalase activity. Along with their lipolytic and proteolytic activities, these

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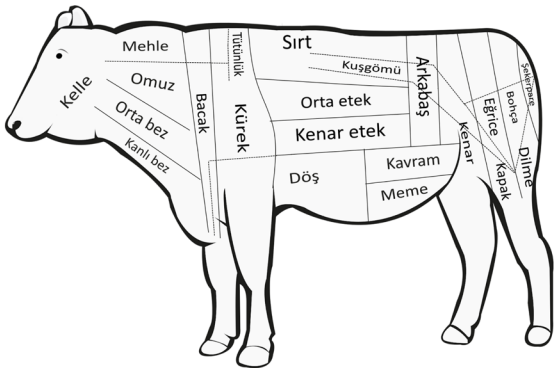

Figure 1. Pastirma parts in beef [Created by the authors based on information from TSE (1991)].

microorganisms play a vital role in color formation, stability, delaying oxidation, and aroma development (Kaya & Kaban, 2010). On the other hand, lactic acid bacteria influence the sensory and textural development of the product through acid production, despite their low proteolytic activity (Aktaş et al., 2005). During the production process, lactic acid bacteria and catalase-positive cocci show significant growth. Catalase-positive cocci can also become the dominant flora in pastirma. These acid-sensitive microorganisms exhibit substantial growth due to the favorable pH of the product (Kaban, 2009).

Studies on pastirma production generally indicates that the moisture content does not fall below 40%. Additionally, the salting stages during pastirma production alter intracellular and extracellular osmotic pressure, causing intracellular water to be removed and reducing water activity, thereby ensuring microbial stability. Many factors affect the final moisture content of pastirma. Differences in moisture values among studies and regions are due to these factors. The most significant factor affecting moisture content is the carcass region selected. Other factors influencing the final moisture content include the amount of salt used, the salting method, the structure of çemen, microbiota, drying duration, and drying method (Doğruer et al., 1995). The aim of this study is to determine the physicochemical and microbiological properties of different pastirma types produced in Kayseri.

2. Material and Methods

2.1. Materials

In this study, twenty different pastirma samples including 3 entrecote, 3 sırt, 4 but, 2 şekerpare, 2 omuz, 1 potuk (special lean pastirma), 1 kuşgömü, 1 sırt tütünlük, 1 dilme, 1 kol, and 1 kürek produced in the Kayseri (Türkiye) were used (Table 1). The pastirma samples were collected under aseptic conditions, transported to the laboratory under appropriate conditions, and stored at 4°C until analysis.

Table 1. Types of pastirma collected from the market

Sample No	*Type*
P1	Entrecote
P2	Potuk (special lean)
P3	Entrecote
P4	Sırt
P5	But
P6	Kuşgömü
P7	Şekerpare
P8	Sırt Tütünlük
P9	But
P10	Dilme
P11	Entrecote
P12	Omuz
P13	Kol
P14	Sırt
P15	But
P16	Sırt
P17	Kürek
P18	Omuz
P19	But
P20	Şekerpare

2.2. Physicochemical Analyses of Pastirma Samples

The moisture contents of the samples were determined by drying in an oven (Nüve, Türkiye). The samples were placed into pre-weighed containers and then transferred to an oven set at 105±2°C for 12 hours. Afterward, the containers were cooled and brought to constant weighing in a desiccator, and their final weights were recorded (Ozturk, 2015).

Ten grams of pastirma samples were taken, and 100 ml of distilled water was added to each. The samples were then homogenized using an Ultra-Turrax homogenizer (IKA, Germany). The homogenized samples were measured with a calibrated pH meter (WTW 720, Germany) (Ozturk, 2015).

2.3. Microbiological Analyses of Pastirma Samples

From the samples delivered to the laboratory in sterile packaging, 10 g of each sample was taken under sterile

conditions and placed in a stomacher bag. Subsequently, 90 ml of sterile maximum recovery diluent solution (MRD, Merck, Germany) was added, and the mixture was homogenized in the masticator homogenizer (IUL, Barcelona, Spain) for 1 minute. Then, serial dilutions of samples were prepared (Ozturk, 2015).

To determine the total mesophilic aerobic bacteria count, Plate Count Agar (PCA, Merck, Germany) medium was used. After incubation at 30°C for 2 days, the colonies formed on the plates were counted (Çakıcı et al., 2015).

Lactic acid bacteria counts of samples were determined using de Man, Rogosa and Sharpe Agar (MRS, Germany) and M17 agar (Merck, Germany). The prepared culture media were inoculated from the dilutions, and the plates were incubated under anaerobic conditions at 30°C for 48 hours. At the end of the incubation period, colonies with colors ranging from white to cream on MRS and M17 agar were counted as lactic acid bacteria (LAB) (Çakıcı et al., 2015).

Total mold and yeast counts of samples were determined using different media including Rose Bengal Chloramphenicol (RBC, Merck, Germany), Dichloran Rose Bengal Chloramphenicol (DRBC, Merck, Germany), Potato Dextrose Agar (PDA, Merck, Germany), Malt Extract Agar (MEA, Merck, Germany), and Czapek-Dox Agar (Merck, Germany). The plates were incubated at 25°C for 5 days. At the end of the incubation period, yeast and mold counts were separately performed (Ozturk, 2015).

3. Results

The moisture and pH values are presented in Table 2. In our study, the lowest moisture content was determined as 34.77%, while the highest was 57.61%. For P6 and P8 samples, the moisture content was below 40%. Additionally, in P1, P3, P4, P5, P10, P11, P13, and P16 samples, the moisture content ranged between 40% and 50%. In contrast, the moisture values of samples with codes P2, P7, P9, P12, P14, P15, P17, P18, P19, and P20 were determined to be above 50%. The average pH values of samples were 5,99 and the values changed between 5.81 and 6.22 in the samples. The highest pH values were determined in the P1 and P11 samples (entrecote) as pH 6.22 and 6.14, respectively.

Different culture media were used to determine the yeast counts in the pastirma samples. The yeast counts ranged from <2.00 to 6.03 log CFU/g on RBC, DRBC, MEA and PDA media. For all samples on Czapek-Dox medium the yeast counts were below the detectable limit (<2.00 log CFU/g). The highest yeast count was observed in the P9 sample (but) for all media except for Czapex-Dox medium (Table 3).

Table 2. Moisture and pH Values of Pastirma Samples

Sample	*pH Value*	*Moisture*
P1	6.22±0.02	36.53±4.04
P2	6.05±0.06	50.24±3.09
P3	5.96±0.01	41.72±0.06
P4	5.89±0.01	39.99±1.84
P5	5.93±0.01	45.49±1.10
P6	6.12±0.01	38.10±0.63
P7	5.83±0.01	50.41±2.25
P8	6.07±0.03	34.77±1.16
P9	5.81±0.01	52.96±4.17
P10	5.84±0.01	48.79±0.91
P11	6.14±0.01	37.88±2.80
P12	6.10±0.01	49.50±4.53
P13	6.04±0.01	45.20±2.04
P14	5.89±0.01	50.34±5.05
P15	5.95±0.05	57.61±1.41
P16	5.96±0.06	40.63±1.43
P17	6.05±0.01	54.89±2.17
P18	6.01±0.04	46.04±4.76
P19	6.05±0.03	51.22±0.44
P20	5.99±0.02	49.12±1.53

The mold counts of pastirma samples ranged between <2.00 and 4.06 log CFU/g, and <2.00 and 4.02 log CFU/g on RBC and MEA media, respectively, and with the highest count observed in the P13 sample (kol). The mold counts on DRBC medium were found to range between <2.00 and 4.01 log CFU/g. The highest mold count for DRBC, PDA and Czapek-Dox media was observed in the sample P11 (entrecote). Mold counts were below the detectable limit (<2.00 log CFU/g) in most the pastirma samples (Table 4).

The TMAB count was found to range between 3.89 and 8.60 log CFU/g, with the highest count observed in the P4 sample. LAB counts of samples ranged from <2 to 5.61 and <2 to 3.64 log CFU/g on MRS and M17 media, respectively. In MRS agar, the highest count was found in the P12 sample, while in M17 agar it was found in the P7 sample (Table 5).

Table 3. Yeast Counts of Pastirma Samples (log CFU/g)

Sample	*Yeast Count by Media Type*				
	RBC	*DRBC*	*PDA*	*MEA*	*Czapek-Dox*
P1	4.93±0.47	5.16±0.17	5.32±0.07	5.27±0.15	<2
P2	<2	<2	<2	<2	<2
P3	<2	<2	<2	<2	<2
P4	5.11±0.10	5.09±0.08	5.15±0.11	5.14±0.17	<2
P5	<2	<2	<2	<2	<2
P6	5.45±0.12	5.40±0.12	5.35±0.24	5.28±0.17	<2
P7	4.61±0.33	4.61±0.33	4.35±0.07	4.48±0.01	<2
P8	5.25±0.11	5.19±0.25	5.09±0.12	5.02±0.03	<2
P9	5.99±0.01	5.93±0.04	6.03±0.32	6.03±0.16	<2
P10	5.23±0.07	5.02±0.03	4.77±0.09	4.97±0.25	<2
P11	<2	<2	<2	<2	<2
P12	3.92±0.11	4.13±0.25	3.24±0.34	4.17±0.18	<2
P13	<2	<2	<2	<2	<2
P14	<2	3.15±0.21	<2	3.15±0.21	<2
P15	5.19±0.16	5.37±0.06	5.36±0.21	5.35±0.14	<2
P16	<2	<2	<2	<2	<2
P17	<2	<2	<2	<2	<2
P18	4.39±0.55	3.85±0.21	3.74±0.37	4.06±0.08	<2
P19	4.23±0.33	4.31±0.43	4.25±0.35	4.09±0.12	<2
P20	<2	<2	<2	<2	<2

Table 4. Mold Counts of Pastirma Samples (log CFU/g)

Sample	*Mold Count by Media Type*				
	RBC	*DRBC*	*PDA*	*MEA*	*Czapex Dox*
P1	3.24±0.09	3.28±0.03	<2	3.27±0.05	3.15±0.21
P2	<2	<2	<2	<2	<2
P3	<2	<2	<2	<2	<2
P4	<2	<2	<2	<2	<2
P5	<2	<2	<2	<2	<2
P6	3.24±0.34	2.95±0.07	3.15±0.21	2.98±0.03	3.10±0.28
P7	<2	<2	<2	<2	<2
P8	<2	<2	<2	<2	<2
P9	<2	<2	<2	<2	<2
P10	<2	<2	<2	<2	<2
P11	3.89±0.16	3.98±0.03	3.89±0.16	3.98±0.03	3.85±0.21
P12	3.39±0.55	3.24±0.34	3.35±0.49	3.15±0.21	3.57±0.38
P13	3.85±0.21	3.25±0.07	3.30±0.43	3.95±0.07	3.92±0.11
P14	<2	3.17±0.24	3.80±0.28	<2	<2
P15	<2	3.25±0.10	<2	<2	3.24±0.34
P16	<2	<2	<2	<2	<2
P17	<2	<2	<2	<2	<2
P18	<2	<2	<2	<2	<2
P19	<2	<2	<2	<2	<2
P20	<2	<2	<2	<2	<2

Table 5. TMAB and LAB Counts of Pastirma Samples (log CFU/g)

Sample	*TMAB*	*LAB*	
		MRS	*M17*
P1	8.37±0.30	5.37±0.24	<2
P2	5.17±0.18	3.46±0.20	<2
P3	6.63±0.09	4.37±0.37	3.27±0.38
P4	8.60±0.20	5.59±0.17	3.09±0.12
P5	5.80±0.28	2.37±0.16	<2
P6	8.17±0.24	5.55±0.14	<2
P7	7.62±0.20	5.46±0.12	3.64±0.48
P8	7.46±0.28	4.26±0.26	<2
P9	7.56±0.12	5.71±0.40	<2
P10	6.80±0.15	4.04±0.11	<2
P11	6.63±0.21	4.90±0.20	2.51±0.36
P12	7.95±0.19	5.61±0.20	2.60±0.14
P13	8.04±0.10	5.50±0.15	3.52±0.31
P14	8.15±0.24	5.59±0.35	3.16±0.23
P15	8.29±0.30	5.50±0.09	3.51±0.26
P16	4.16±0.23	<2	<2
P17	4.85±0.21	<2	<2
P18	4.95±0.07	4.21±0.30	3.13±0.18
P19	4.98±0.03	<2	<2
P20	3.89±0.16	<2	<2

4. Discussion

In this study, the pH values of pastirma samples ranged from 5.81 to 6.22. The ideal pH for pastirma should not exceed 6.0. The pH values in our samples were close to this limit. According to Article 7 of the Turkish Food Codex Meat and Meat Products Communiqué (2012), the characteristics of pastirma are as follows: excluding çemen, the moisture content must not exceed 45% by weight, the pH value must not exceed 6.0, the salt content in dry matter must not exceed 7% by weight, and the çemen content must not exceed 10% by weight.

Differences in the chemical properties of pastirma may result from the use of meat from different regions, the structure of çemen, the amount of salt, the salting method, drying, storage conditions, and events occurring during the drying period (Doğruer et al., 1995).

According to the study conducted by Tekinşen and Doğruer (2000), the moisture values were determined as 34.17%, 41.17%, 33.52%, and 36.92%, for kuşgömü, bohça, sırt, and şekerpare respectively. On the other hand, Ceylan (2009) and Ceylan and Aksu (2011) reported moisture values to be between 46.61-47.36% in the sırt, şekerpare and bohça samples. In the other studies, the moisture contents of pastirma samples were determined between 38.98 and 51.51% (Aksu and Kaya 2001; Doğruer et al.,1995; Gürbüz 1994; Hastaoğlu 2011; Özeren 1980).

In the study conducted by Ceylan & Aksu (2011), the average pH values were determined as 5.86, 5.79 and 5.82 for sırt, bohça, şekerpare, respectively. In the other studies, the average pH values of pastirma samples were pH 5.54, 5.70, 5.72 and 5.88 (Doğruer et al., 1995; Gürbüz 1994; Hastaoğlu 2011; Özdemir et al., 1999). In another study, pH values were determined to be between 5.39 and 5.80 in the 60 different samples (Elmalı et al., 2007).

Numerous microbiological studies have been conducted on pastirma samples collected from the market. Doğruer et al. (1995) reported that the average yeast and mold counts as 1.2×10^5 CFU/g. In the study conducted by Özdemir et al. (1999), the mold count was found to be $<2.0\times10^2$ CFU/g and the yeast count ranged from $<2.0\times10^2$ to 10^5 CFU/g. In the similarly study, the yeast and mold counts ranged from <2.00 to 5.76 log CFU/g (Aksu and Kaya, 2001). In another study, the average yeast and mold counts of pastirma samples were found between <2 and 7.24 log CFU/g (Çakıcı, 2012).

The microbiology of pastirma can vary significantly. This variability is caused by factors such as the microbiota of the meat and the microbiota of spices and water used in çemen production. In the study, the total aerobic bacterial count was found to range between 5.00 and 8.39 log CFU/g. Lactic acid bacteria (LAB) counts were determined to exceed 1.0×10^7 CFU/g (Aksu & Kaya, 2001). Çakıcı (2012) found that the LAB and TMAB counts ranged from 5.18 to 6.81 and 6.20 to 7.59 log CFU/g, respectively. Although there are differences compared to our study, the TMAB and LAB counts were found to be within similar ranges in log CFU/g.

5. Conclusions

As a traditional product, pastirma exhibits significant variation in its production methods, resulting in differences in physicochemical properties such as moisture and pH. Additionally, microbial counts, including those of lactic acid bacteria (LAB), total mesophilic aerobic bacteria (TMAB), and yeast and mold, varied substantially among samples. From a consumer perspective, it is crucial to preserve the diversity in production while minimizing undesirable variations that could negatively impact consumer satisfaction. Thus, standardizing diverse production methods emerges as a critical issue to ensure consistent quality while maintaining the traditional character of pastirma.

Declaration of Competing Interest

The authors declare that they have no financial or non-financial competing interests.

Author's Contributions

C. Çeviker (0000-0002-4748-954X): *Definition, Data Collection, Investigation, Methodology.*
C. Karaköse: *Definition, Data Collection, Investigation, Methodology.*
G. Kahraman: *Definition, Data Collection, Investigation, Methodology.*
N. Aydın: *Definition, Data Collection, Investigation, Methodology.*
İ. Öztürk (0000-0003-1434-4763): *Definition, Investigation Conceptualization, Writing, Editing, Methodology, Supervision.*

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The Role of Vitamin D in Parkinson's Disease

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Abstract

Parkinson's disease (PD) is a progressive neurodegenerative disorder marked by tremor, rigidity, bradykinesia, and postural instability, along with non-motor symptoms that can cause disability. Vitamin D, a fat-soluble secosteroid, influences gene expression by binding to the vitamin D receptor (VDR). It is essential for calcium homeostasis and metabolism and is also linked to various health conditions, including PD. In recent years, a high prevalence of vitamin D deficiency has been observed in PD patients. The enzymes converting vitamin D to its active form, VDR, and 1α-hydroxylase, are highly expressed in the substantia nigra. These findings indicate that low vitamin D levels may cause dysfunction or cell death in this brain region. Vitamin D impacts several biological processes in the central nervous system, including neurotransmission in dopaminergic circuits. Studies show lower vitamin D levels in Parkinson's patients compared to healthy controls. Links have been found between vitamin D levels and non-motor symptoms like mood disorders, orthostatic hypotension, and olfactory dysfunction, as well as motor severity. However, information on vitamin D's effects on non-motor symptoms is limited. This review seeks to critically examine the relationship between vitamin D and PD, focusing on the potential mechanisms through which vitamin D may influence the development, progression, and clinical management of PD. Additionally, it aims to evaluate the role of vitamin D in the prevention of PD and its therapeutic potential as an adjunctive treatment in patients with Parkinson's disease.

Keywords: Vitamin D, Medical nutrition therapy, Parkinson's disease.

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1. Introduction

Vitamin D refers to a group of fat-soluble secosteroids that can be synthesized in the skin through exposure to sunlight or obtained through dietary intake (Fullard & Duda, 2020). The biological effects of vitamin D are primarily mediated by its binding to the vitamin D receptor (VDR), which modulates gene expression both directly and indirectly (Shirvani et al., 2020). Initially recognized for its essential role in regulating calcium homeostasis and bone metabolism, vitamin D was also noted in the 1930s and 1940s for its beneficial effects in treating conditions such as psoriasis, asthma, and rheumatoid arthritis (McCullough et al., 2019). Over time, its association with a broad range of health conditions—including cardiovascular disease, cancer, autoimmune disorders, and neurodegenerative diseases such as Parkinson's disease (PD)—has become increasingly evident (Bouillon, 2018). The potential neuroprotective effects of vitamin D have garnered significant attention, particularly in relation to neurodegenerative diseases. Several mechanisms through which vitamin D may exert neuroprotection have been proposed. One such mechanism involves the influence of vitamin D on neurotrophic factors, which are essential for the survival, development, and function of neurons. By promoting the synthesis of these factors, vitamin D can support neuronal health and protect against degeneration. Additionally, vitamin D has been shown to regulate nerve growth, further contributing to neuronal maintenance and repair processes (Garcion et al., 2002). Furthermore, vitamin D's neuroprotective role is thought to be mediated through its ability to protect neurons from cytotoxicity. Cytotoxicity, which results from the accumulation of toxic substances or oxidative stress, is a critical factor in the pathogenesis of neurodegenerative diseases. Vitamin D's antioxidant properties may help reduce oxidative damage, thereby preserving neuronal function and reducing the progression of neurodegenerative disorders like PD. These mechanisms, including the regulation of neurotrophic factors, nerve growth, and cytotoxicity,

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collectively contribute to the neuroprotective properties of vitamin D, which may play a significant role in the prevention and management of neurodegenerative diseases such as Parkinson's disease. Further research is needed to fully elucidate these mechanisms and their impact on PD pathophysiology (Liewellyn et al., 2010).

PD is the second most common degenerative disease of the central nervous system (CNS) after Alzheimer's disease. PD is a complex and progressive neurodegenerative disorder characterized by motor symptoms such as bradykinesia, resting tremor, rigidity, postural instability, and gait disturbances (Barichella et al., 2022). In addition, PD is characterized by various non-motor symptoms (e.g., hyposmia, constipation, urinary dysfunction, orthostatic hypotension, cognitive impairment, depression, and rapid eye movement sleep behavior disorder), which may lead to disability. These non-motor symptoms can emerge several years, or even decades, before the onset of motor features (Bloem et al., 2021). The pathophysiology of PD is defined by the presence of intraneuronal cytoplasmic inclusions, primarily composed of α-synuclein aggregates known as Lewy bodies, leading to dopaminergic loss in the substantia nigra pars compacta (SNpc) and other nuclei within the CNS (Tolosa et al., 2021). The underlying molecular pathogenesis involves α-synuclein proteostasis, encompassing mitochondrial function, oxidative stress, calcium homeostasis, axonal transport, and neuroinflammation, along with other pathways and mechanisms (Poewe et al., 2017). Although the pathophysiology of PD has been well characterized, its exact etiology remains unclear. Recently, among various etiological factors, low vitamin D status has emerged as a potentially modifiable risk factor for PD (Barichella et al., 2022). This review aims to examine the relationship between vitamin D and Parkinson's disease, as well as the role of vitamin D in the prevention and treatment of the disease.

2. Sources and Metabolism of Vitamin D

Vitamin D is primarily synthesized in the skin from 7-dehydrocholesterol under the influence of ultraviolet B radiation. Although it is a fat-soluble hormone, it can also be obtained from dietary sources. Vitamin D3 is biologically inert and requires two hydroxylation steps to become active (Barichella et al., 2022). The first hydroxylation occurs in the liver, where the enzyme vitamin D-25-hydroxylase converts vitamin D into 25-hydroxyvitamin D3 (25-OH-D3) or calcidiol, which is the circulating form. Subsequently, 25-OH-D3 is converted into 1,25-dihydroxyvitamin D3 (1,25-(OH)2D3), also known as calcitriol, by 25-hydroxyvitamin D-1α-hydroxylase or 1α-hydroxylase (Fullard & Duda, 2020). This second step takes place in the kidneys, particularly in the proximal convoluted tubule cells, and is regulated by blood calcium and phosphorus levels (Plum & DeLuca, 2010). After sun exposure, the skin converts 7-dehydrocholesterol into cholecalciferol (Bytowska et al., 2023). Therefore, insufficient exposure to sunlight may result in low vitamin D levels (Zhou et al., 2019).

Vitamin D can also be obtained from certain dietary sources. In nature, dietary vitamin D exists in two forms: vitamin D3 (25-OH-D3) or cholecalciferol, which is found in animal-derived sources such as bluefish, egg yolk, and meat, and vitamin D2 (25-OH-D2) or ergocalciferol, which is primarily present in nuts, almonds, walnuts, mushrooms, beans, and leafy green vegetables (Barichella et al., 2022). Similar to cholecalciferol, ergocalciferol must undergo hydroxylation at the 25 and 1α positions to become active. The total amount of cholecalciferol and ergocalciferol is generally referred to as 25-OH-D (Sosa & Gómez, 2020). Since only a limited number of foods provide a reasonable amount of vitamin D, dietary intake is often insufficient (Barichella et al., 2022).

Currently, vitamin D is considered a hormone rather than a vitamin (Zhou et al., 2019). In addition to its role in calcium and phosphorus metabolism, vitamin D also plays a role in inflammatory response (Kempker et al., 2012), glucose and lipid metabolism (Salamon et al., 2014), and cardiac and vascular regulation (Carthy et al., 1989). The biological functions of vitamin D are mediated through its binding to vitamin D receptors (VDRs), which belong to the steroid hormone receptor superfamily. VDRs are widely expressed in various tissues, including the kidneys, bones, intestines, muscles, pancreas, and central nervous system (Zhou et al., 2019).

3. Vitamin D Deficiency: Definition and Prevalence

The clinical practice guidelines on vitamin D issued by the Endocrine Society Task Force have defined a threshold level of 50 nmol/L (or 20 ng/mL) as vitamin D deficiency. A threshold of <30 nmol/L (or 12 ng/mL) has been shown to significantly increase the risk of osteomalacia and nutritional rickets and is, therefore, considered severe vitamin D deficiency. Serum 25-OH-D concentrations between 50 nmol/L and 75 nmol/L (<30 ng/mL) should be classified as vitamin D

insufficiency. In contrast, 25-OH-D concentrations ranging from 75 to 150 nmol/L represent the normal range (Holick et al., 2011). In summary, serum vitamin D levels are generally defined as deficient at <20 ng/mL, insufficient at 20–30 ng/mL, and sufficient at >30 ng/mL. Low vitamin D status, or hypovitaminosis D, encompasses both deficiency and insufficiency and has emerged as a highly prevalent condition worldwide (Barichella et al., 2022).

Low vitamin D levels are more frequently observed in childhood and older age. Severe vitamin D deficiency has been reported with a prevalence ranging from 85% to 99%, particularly in patients affected by liver and/or kidney failure (Amrein et al., 2020). Vitamin D deficiency has been associated with various pathological changes in multiple organ systems and has been linked to an increased incidence of several chronic diseases, including multiple sclerosis (Koduah et al., 2017), cardiovascular disease (Giovannucci et al., 2008), cancer (Kilkkinen et al., 2008), type 2 diabetes (Knekt et al., 2008), Alzheimer's disease (Littlejohns et al., 2014), and Parkinson's disease (Bytowska et al., 2023).

4. Parkinson's Disease

Parkinson's disease (PD) is one of the most common neurodegenerative disorders, characterized by the loss of dopaminergic neurons in the substantia nigra (Zhou et al., 2019). Individuals over the age of 60 are at a higher risk of developing PD (Hirsch et al., 2016). Due to the aging population, the incidence of PD is expected to increase further in the future (Bytowska et al., 2023). The etiology of PD remains unknown and is likely multifactorial. The exact mechanism underlying neurodegeneration in PD has not yet been fully elucidated (Lv et al., 2020). Both genetic and environmental factors, including specific genetic mutations (Corti et al., 2011), sex, pesticide exposure (Allen & Levy, 2013), and the use of calcium channel blockers (Lang et al., 2015), have been reported to contribute to the development of Parkinson's disease. Due to its uncertain etiology, no medication has been proven to cure PD (Lv et al., 2020). Therefore, PD currently remains an incurable disease. The primary goals are to alleviate symptoms, reduce discomfort, and slow disease progression to help patients better manage their daily activities (Bytowska et al., 2023).

Symptoms can be classified as motor and non-motor. The main motor symptoms include bradykinesia, postural instability, and resting tremors. Non-motor symptoms include depression, dementia, sleep disorders, and mild personality changes. In Parkinson's disease, dopamine production is impaired due to the degeneration of the substantia nigra (Jankovic & Tan, 2020). Studies conducted on rodent models of PD have observed that vitamin D treatment exerts a protective effect on dopaminergic neurons in the substantia nigra (Rimmelzwaan et al., 2016).

5. The Relationship of Vitamin D to Parkinson's Disease

Vitamin D deficiency in Parkinson's disease (PD) was first identified by Sato et al. in 1997 (Sato et al., 1997). Since then, numerous studies have observed that the prevalence of vitamin D deficiency and insufficiency in PD is higher compared to controls (Ding et al., 2013; Fullard & Duda, 2020). After the discovery that vitamin D receptors (VDR) and 1α-hydroxylase, the enzyme responsible for converting vitamin D into its active form, are highly expressed in the substantia nigra, it has been hypothesized that insufficient circulating vitamin D levels may lead to dysfunction or cell death in the substantia nigra (Eyles et al., 2005). A long-term cohort study found that the incidence of PD was three times higher in individuals with the lowest serum 25(OH)D concentrations compared to those with the highest concentrations (Knekt et al., 2010). In a study conducted on 300 individuals selected from the Clinical Research in Neurology database (100 Parkinson's patients, 100 Alzheimer's patients, and 100 healthy controls), the prevalence of vitamin D deficiency (defined as concentrations below 30 ng/mL) was reported to be significantly higher in Parkinson's patients (55%) compared to both healthy controls (36%) and Alzheimer's patients (41%). Additionally, 47.2% of Parkinson's patients were found to have vitamin D insufficiency (20-30 ng/mL) (Evatt et al., 2008).

In the Mini-Finland Health Survey (Mini-Fin Study), which examined the correlation between vitamin D levels and the incidence of Parkinson's disease (PD), higher vitamin D levels were observed to be associated with a lower risk of developing PD over a 29-year follow-up period (Knekt et al., 2010). It was reported that the risk of PD was 65% lower in individuals with serum vitamin D concentrations above 50 nmol/L compared to those with concentrations below 25 nmol/L (Knekt et al., 2010). In a prospective observational study comparing 145 Parkinson's patients with 94 healthy controls, it was observed that at baseline, Parkinson's patients had significantly lower serum vitamin D concentrations than age-matched controls. Similarly, after an 18-month follow-up, individuals with PD were found to have lower mean

serum 25(OH)D concentrations compared to controls (Sleeman et al., 2017). Since dermal synthesis is the primary source of vitamin D, some studies have focused on the relationship between outdoor work and the risk of Parkinson's disease. One study found that Danish men who worked outdoors had a lower likelihood of developing PD compared to those who worked indoors (Kenborg et al., 2011). A study conducted on 69,010 Parkinson's patients in France reported that the number of prescriptions for Parkinson's medications was lower in geographic regions with higher UV-B radiation. However, the role of diet and dietary vitamin D intake in the risk of PD has not been sufficiently explored in the literature (Kravietz et al., 2017). One study reported an inverse relationship between the risk of Parkinson's disease and serum levels of all forms of vitamin D, including dietary 25-OH D2, which is independent of sun exposure (Wang et al., 2015). These findings suggest the possibility that the risk of Parkinson's disease associated with vitamin D may not be solely due to a lack of sun exposure. Other mechanisms, such as gastrointestinal dysfunction—a common non-motor dysfunction in PD—which may impair vitamin D2 absorption, could also be involved (Lubomski et al., 2020).

In addition to studies demonstrating an association between vitamin D and PD, there are also studies that do not support this relationship. In a prospective study with an average follow-up of 17 years, although an increase in PD risk was reported between vitamin D levels >30 ng/mL and <20 ng/mL, no significant association was found between vitamin D status and the risk of Parkinson's disease (Shrestha et al., 2016). In the Parkinson Associated Risk Syndrome (PARS) study, no significant difference was found in total plasma vitamin D levels among high-risk patients compared to all other groups (Fullard et al., 2017). The inconsistent findings regarding the relationship between vitamin D and Parkinson's disease are thought to be due to differences in the geography, dietary habits, physical activity, and socioeconomic conditions of the studied populations (Barichella et al., 2022).

Due to the limited mobility and gastrointestinal symptoms observed in PD patients, low vitamin D levels may also be a consequence of the disease (Ly et al., 2020). However, several studies have suggested that vitamin D deficiency may be associated with the etiology of Parkinson's disease (Newmark & Newmark, 2007; Evatt et al., 2008; Fullard et al., 2017). A study reported that even in Parkinson's patients with normal ambulation and gastrointestinal function, the prevalence of vitamin D deficiency was still higher (Evatt et al., 2011). Newmark and colleagues concluded that chronic vitamin D deficiency may not simply be a result of the disease but could be linked to the pathogenesis or progression of Parkinson's disease (Newmark & Newmark, 2007; Knekt et al., 2010).

Despite numerous studies reporting a link between low serum vitamin D levels and Parkinson's disease (PD), inconsistencies remain due to variations in vitamin D measurement standards and threshold definitions. These methodological differences hinder cross-study comparisons and affect the interpretation of results. Additionally, geographic factors (e.g., sun exposure), dietary habits, and genetic variations—particularly in vitamin D receptor (VDR) polymorphisms—further contribute to heterogeneity in findings. To address these challenges, future research should adopt standardized measurement protocols, account for environmental and genetic influences, and conduct large-scale randomized controlled trials to clarify the potential causal role and therapeutic efficacy of vitamin D in PD.

6. Pathophysiology of Vitamin D and Parkinson's Disease

The pathophysiological cause of Parkinson's disease (PD) is the loss of dopaminergic neurons (DA) in the substantia nigra (SN) of the midbrain, primarily characterized by the formation of Lewy bodies, which consist of α-synuclein protein aggregations (Lv et al., 2020). Vitamin D plays a fundamental role in various diseases, including dermatological conditions, cardiovascular disorders, autoimmune diseases, and neurological disorders such as Parkinson's disease, exerting biological effects on multiple processes (Barichella et al., 2022). Since vitamin D is a fat-soluble hormone capable of crossing the blood-brain barrier, it exerts effects on the CNS. Additionally, the CNS has the ability to synthesize its own vitamin D. Vitamin D has been reported to influence cellular proliferation, differentiation, calcium signaling, neuroprotection, synaptogenesis, amyloid clearance, and the prevention of neuronal death through the CNS (Di Somma et al., 2017). Furthermore, vitamin D has been implicated in dopaminergic neurotransmission as well as in cellular processes such as neurogenesis and neurite outgrowth (DeLuca & Li, 2011). It has been determined that vitamin D increases the expression of tyrosine hydroxylase enzyme in chromaffin cells of the adrenal medulla, which exhibit surface vitamin D receptors (VDRs), enhances catecholamine production, and plays a role in both dopamine synthesis and storage in the CNS (Pertile et al., 2016). In an experimental study,

vitamin D was observed to mitigate neurotoxicity induced by 6-hydroxydopamine (a toxic compound) in rats, providing protection against dopamine depletion in the SNpc (Wang et al., 2001). In vitro studies have demonstrated that vitamin D may upregulate the expression of glial cell line-derived neurotrophic factor (GDNF), particularly in the striatum, suggesting its protective role in PD (Sanchez et al., 2002). Moreover, vitamin D has been reported to counteract oxidative stress in the brain by reducing reactive oxygen species through various mechanisms, including PARP1 inhibition (Barichella et al., 2022). A study indicated that vitamin D may prevent α-synuclein aggregation through the expression of calbindin-D28k, a calcium-binding protein, thereby exhibiting a neuroprotective role (Rcom et al., 2017). These effects, alongside others, suggest that vitamin D may influence the pathophysiology of Parkinson's disease via mechanisms such as neuroinflammation, oxidative stress, and dopamine production, which may contribute to disease progression. In conclusion, inadequate vitamin D status may contribute to the loss of dopaminergic neurons in the brain and thus play a role in the development of PD (Pignolo et al., 2022).

VDR and 1α-hydroxylase, which converts vitamin D into its active form, are expressed in the neurons of the substantia nigra in Parkinson's disease (PD) (Suzuki et al., 2013). The active form of vitamin D, 1,25-$(OH)_2D_3$, binds to the vitamin D receptor (VDR), activating it and regulating gene transcription. Both VDR and the 1α-hydroxylase enzyme are also expressed in other tissues, including neuronal and glial cells (Rimmelzwaan et al., 2016). Therefore, vitamin D has been suggested to play a role in brain development and neurodegenerative diseases such as PD and dementia, exerting neuroprotective effects on brain function (Eyles et al., 2005). In particular, VDR expression in dopaminergic regions of the brain implies a direct regulatory influence of vitamin D on the survival and function of these neurons, further supporting its potential involvement in PD pathophysiology. Moreover, vitamin D is believed to modulate microglial activation and inflammatory cytokine production, which are key contributors to neuroinflammation in PD. This modulation of immune responses may reduce chronic inflammation in the substantia nigra, thereby preventing or delaying dopaminergic neuron degeneration.

Genetic studies have demonstrated an association between VDR gene polymorphisms and the risk of PD (Butler et al., 2011). Muscle and motor impairments have been observed in VDR knockout mice (Burne et al., 2005). The FokI C allele of VDR, which is thought to enhance signal transduction efficiency, has been reported to be associated with milder forms of PD (Suzuki et al., 2012). Among the genes regulated by VDR in the hippocampus, several have been implicated in the pathophysiology of PD, including CCAAT/enhancer-binding protein beta (CEBPB), Peripheral myelin protein 22 (PMP22), Plasma membrane calcium-transporting ATPase 3 (ATP2B3), Glutamate receptor AMPA 3 (GRIA3), Neurotrophic receptor tyrosine kinase 2 (NTRK2), DNA methyltransferase 3 alpha (DNMT3A), Tenascin R (TNR), and Glutamate ionotropic receptor NMDA type subunit 2A (GRIN2A). These findings suggest that vitamin D levels and VDR gene polymorphisms may be associated with the incidence and progression of PD (Lang et al., 2020). These polymorphisms may influence individual responses to vitamin D and contribute to variability in susceptibility and clinical progression of PD. Therefore, the consideration of genetic variability in future clinical trials may enhance understanding of differential therapeutic responses to vitamin D supplementation.

1,25-$(OH)_2D_3$ is synthesized in the human brain and influences the function of various structures, including the substantia nigra. Since 1,25-$(OH)_2D_3$ is a potent regulator of neuronal gene expression, it has been classified as a neurosteroid (Landel et al., 2018). In neurons, vitamin D suppresses oxidative stress, inhibits inflammation, and stimulates neurotrophin production. In addition to preventing vascular damage, vitamin D exerts neuroprotective effects through the upregulation of neurotrophins, improved metabolism, and positive effects on cardiovascular function (AlJohri et al., 2019; Lang & Leibrock, 2019; Lang et al., 2020). Moreover, vitamin D has been shown to stimulate the differentiation of dopaminergic neurons and upregulate dopamine synthesis and metabolism (Pertile et al., 2016; AlJohri et al., 2019). These findings underscore the multi-faceted role of vitamin D in maintaining dopaminergic neuron health and regulating critical processes involved in PD pathogenesis. Nonetheless, despite these promising mechanisms, current evidence remains inconclusive, and conflicting findings persist in the literature regarding the extent of vitamin D's protective effects in PD.

In neuroblastoma cells, vitamin D has been shown to reduce cell proliferation and promote differentiation. Thus, vitamin D supports the growth, survival, proliferation, and differentiation of neurons and neural stem cells (AlJohri et al., 2019). Vitamin D deficiency may compromise neuronal development, dopamine transport, and metabolism. Additionally,

vitamin D is a potent inhibitor of cyclooxygenase (COX), an inflammatory enzyme reported to play a role in the pathophysiology of PD. Consequently, vitamin D is thought to have a beneficial impact on the clinical course of Parkinson's disease (Lang et al., 2020). Given the complexity of PD etiology and the interplay between environmental and genetic factors, future studies should adopt stratified approaches based on vitamin D status, genetic background, and clinical phenotype to more precisely delineate the role of vitamin D in PD. Randomized controlled trials are particularly needed to evaluate vitamin D's efficacy, focusing on parameters such as disease stage, motor and non-motor symptoms, and relevant biomarkers.

7. Effects of Vitamin D on PD Symptoms and Prognosis

Vitamin D deficiency may have an impact on the progression of Parkinson's disease (PD) as well as on its clinical motor and non-motor symptoms (Pignolo et al., 2022). Studies conducted in humans have reported that serum 25(OH)D levels are lower in Parkinson's patients compared to controls, and higher 25(OH)D levels have been associated with better motor function (Topal et al., 2010; Evatt et al., 2011). In one study, low 25(OH)D levels were observed to be associated with severe postural instability, freezing of gait, and postural abnormalities (Moghaddasi et al., 2013). Additionally, higher 25(OH)D levels have been linked to neuroprotection in rodent models of PD (Wang et al., 2001; Rimmelzwaan et al., 2016). Other studies have reported an inverse relationship between serum 25-hydroxyvitamin D levels and the severity of Parkinson's disease (Hiller et al., 2018; Bytowska et al., 2023). Vitamin D supplementation has been shown to reduce the rate of motor function deterioration, as determined by both the Hoehn and Yahr scale and the Unified Parkinson's Disease Rating Scale (UPDRS) (Suzuki et al., 2013). In a case-control study, higher serum 25(OH)D$_3$ levels were found to be associated with better automatic postural responses in Parkinson's disease (Peterson et al., 2013), while a clinical study reported that the administration of 1200 IU of vitamin D supplementation prevented the worsening of scores on scales (H&Y and UPDRS) measuring the severity of Parkinson's disease (Suzuki et al., 2013). In addition to its symptomatic effects on motor function, vitamin D may also exert neurotrophic or neuroprotective effects in Parkinson's disease. Higher vitamin D levels have been associated with better balance, and vitamin D supplementation has been reported to have a positive impact on PD motor symptoms (Peterson et al., 2013; Suzuki et al., 2013). Studies have indicated that as 25(OH)D$_3$ concentrations decrease in Parkinson's patients, the severity of motor symptoms increases (Suzuki et al., 2012; Zhou et al., 2019). Prospective observational studies have also found a negative relationship between baseline vitamin D status and the severity of PD motor symptoms during disease progression (Suzuki et al., 2013; Sleeman et al., 2017). Therefore, vitamin D supplementation may delay the worsening of symptoms in Parkinson's patients. A cross-sectional observational study also reported an association between postural balance and serum vitamin D levels (Peterson et al., 2013).

Limited data are available regarding the relationship between vitamin D and non-motor symptoms in PD. In general, individuals with low 25(OH)D$_3$ levels have been reported to experience worsening non-motor symptoms such as excessive daytime sleepiness, olfactory dysfunction, and cognitive decline (Kim et al., 2018; Plantone et al., 2022). A study investigating olfactory dysfunction, a symptom observed in PD, reported that 25(OH)D$_3$ levels correlated with the severity of olfactory impairment in Parkinson's disease (Kim et al., 2018). In addition to its association with dementia and olfactory function in PD patients, serum 25(OH)D$_3$ concentrations may also influence gastric emptying time (Kwon et al., 2016) and orthostatic hypotension (Jang et al., 2015).

It has been suggested that vitamin D is a regulator of the renin-angiotensin system (RAS). RAS plays a role in blood pressure regulation and affects the sympathetic nervous system; therefore, vitamin D-related dysfunction in RAS may lead to sympathetic system impairment (Fullard et al., 2020). Numerous studies involving both PD patients and the general population have associated vitamin D status with orthostatic hypotension (Duval et al., 2015; Ometto et al., 2016). In one study, 55 PD participants were divided into two groups based on the presence or absence of orthostatic hypotension, and it was determined that serum 25-hydroxyvitamin D and calcitriol levels were significantly lower in the group with orthostatic hypotension (Jang et al., 2015).

Olfactory dysfunction is also a common non-motor symptom in Parkinson's disease, with a prevalence of 50–90% (Fullard et al., 2020). It has been reported that vitamin D plays a role in the pathogenesis of olfactory dysfunction in Parkinson's disease through various potential mechanisms involving calcitriol, the active form of vitamin D (Kim et al., 2018). Additionally, alterations in dopamine and

acetylcholine signaling have been shown to contribute to olfactory dysfunction in Parkinson's disease (Bohnen et al., 2011). Calcitriol has been reported to increase the activity of choline acetyltransferase and tyrosine hydroxylase, which are enzymes responsible for the synthesis of acetylcholine and dopamine, thereby exhibiting a neuroprotective effect (Wrzosek et al., 2013). In addition to the regulation of acetylcholine, vitamin D may also play a role in the clearance of amyloid-beta, both of which are involved in the pathogenesis of cognitive impairment in Parkinson's disease (Fullard et al., 2020). Multiple studies have demonstrated that VDR and enzymes involved in D3 metabolism are expressed in the central nervous system, particularly in hippocampal regions (Yilmazer et al., 2013; Fullard et al., 2020). Animal studies have shown that vitamin D deficiency negatively affects hippocampal learning and memory through gene expression and neural development (Liang et al., 2018). These studies propose potential mechanisms for the impact of vitamin D on cognitive decline in Parkinson's disease; however, further research is needed to determine whether vitamin D status influences cognition in PD and whether supplementation may help prevent or improve cognitive decline (Fullard et al., 2020).

8. Osteoporosis and Fracture Risk in Parkinson's Disease

An increased prevalence of osteoporosis and osteopenia has been reported in patients with Parkinson's disease (PD), and PD is considered a cause of secondary osteoporosis (Lv et al., 2020). A study conducted in Korea determined that 6542 out of 35,663 patients with Parkinson's disease (18.3%) experienced osteoporosis, with fractures occurring most frequently within the first six months following the onset of Parkinson's disease and decreasing three years after diagnosis (Park et al., 2019). Bone loss and fractures in Parkinson's disease are reported to be multifactorial, with vitamin D deficiency being one of the contributing factors (Sato et al., 1997; Metta et al., 2017). Vitamin D deficiency is a well-known risk factor for osteoporosis and bone fractures (Suzuki et al., 2013). A meta-analysis of randomized controlled trials has reported that vitamin D supplementation reduces the risk of falls in elderly individuals, suggesting that vitamin D deficiency may increase the risk of falls (Bischoff-Ferrari et al., 2009). Patients with Parkinson's disease have lower bone mineral density and a higher risk of falls and hip fractures compared to age-matched controls; however, these risks may also result from factors unrelated to PD, such as advanced age, low body mass index, and limited sun exposure (Suzuki et al., 2013).

A decline in bone mass is a common finding in Parkinson's disease, affecting 91% of women and 61% of men (Barichella et al., 2022). According to the World Health Organization, osteoporosis is defined as bone mineral density that is 2.5 standard deviations below the mean, whereas osteopenia is defined as bone mineral density between 1.0 and 2.5 standard deviations below the mean for age, race, and sex (Reid, 2020). The reduced bone mass observed in Parkinson's disease appears to be primarily due to decreased mobility, similar to other neurological disorders. However, vitamin D deficiency, along with other endocrine, nutritional, and iatrogenic factors, may play a significant role in bone mass depletion (Barichella et al., 2022). In a cross-sectional study involving Parkinson's patients and healthy controls, lower bone mineral density was observed in the PD group, and an inverse relationship was identified between bone mineral density at the hip and disease severity. These findings suggest a link between osteoporosis and the progression of Parkinson's disease (Gao et al., 2015).

9. Vitamin D Receptor Polymorphisms and Parkinson's Disease

The biological functions of $1,25(OH)_2D_3$ are mediated by the vitamin D receptor (VDR), a member of the nuclear receptor superfamily of transcription factors. Upon ligand binding, VDR interacts with the retinoid X receptor (RXR) to form a heterodimer, which subsequently binds to vitamin D response elements (VDREs) in target genes. It is estimated that $1,25(OH)_2D_3$ regulates more than 200 genes by influencing various cellular processes (Lv et al., 2020).

VDR serves as the principal mediator of vitamin D functions. A transcriptome-wide screening has revealed increased VDR gene expression in blood cells of patients with early-stage Parkinson's disease (Scherzer et al., 2007). Consequently, it has been suggested that polymorphic variants of VDR may also play a role in the pathogenesis of Parkinson's disease. In recent years, the most frequently studied polymorphisms have been BsmI (rs1544410), FokI (rs10735810), ApaI (rs7975232), and TaqI (rs731236) (Lv et al., 2020). Several studies have investigated the association between VDR polymorphisms and Parkinson's disease; however, conclusive results have not always been obtained. Four classical VDR polymorphisms (TaqI, ApaI, BsmI, and FokI) have been examined for their potential associations with

Parkinson's disease, with the FokI genotype appearing to be the most strongly associated with Parkinson's disease risk (Barichella et al., 2022). A study has reported that Parkinson's patients with higher vitamin D levels exhibit lower motor severity symptoms and that the VDR FokI CC genotype is more prevalent among these individuals. Based on this finding, it has been suggested that the worsening of motor severity in Parkinson's patients carrying the FokI TT or CT genotypes may be prevented through vitamin D supplementation (Suzuki et al., 2012). A meta-analysis evaluating the associations between all VDR polymorphisms and the risk of Parkinson's disease has identified a relationship between FokI and susceptibility to Parkinson's disease in the general population (Gao et al., 2020).

In polymerase chain reaction-based restriction analysis of VDR gene polymorphisms, the BsmI (B/b) polymorphism has been reported to potentially influence the pathogenesis of Parkinson's disease (PD) (Kim et al., 2005). Additionally, studies conducted in Hungarian, Japanese, and Chinese populations have suggested that the FokI (C/T) polymorphism is significantly associated with PD and that the C allele may increase the risk of the disease (Han et al., 2012; Tanaka et al., 2017). The most significant start codon polymorphism of the VDR gene is the FokI polymorphism, which consists of a long version (T allele) and a shorter protein variant shortened by three amino acids (C allele). Compared to T-VDR, C-VDR has been found to have a better capacity for calcium absorption in the intestines. Consequently, the C allele may contribute to higher vitamin D levels and a reduced risk of PD (Lv et al., 2020). However, research findings also suggest that rather than serving as a protective factor, the C allele may act as a risk factor for Parkinson's disease (Han et al., 2012; Tanaka et al., 2017). A stronger association between the FokI CC genotype and milder forms of PD has been identified in one study (Suzuki et al., 2012). Moreover, the Parkinson Environment Gene (PEG) study, a population-based case-control study on PD, has reported a connection between the FokI polymorphism and cognitive decline in PD (Gatto et al., 2016). However, some studies have failed to establish any relationship between VDR genotypes (BsmI, FokI, ApaI, and TaqI loci) and the risk of Parkinson's disease (Kang et al., 2016; Lv et al., 2020). These findings indicate that the impact of VDR gene polymorphisms on PD risk and their association with vitamin D levels may be influenced by factors such as ethnic differences, environmental exposures, gene-gene and gene-environment interactions, or small sample sizes. Therefore, future research should focus on the interactions between vitamin D levels and VDR gene polymorphisms in PD while also considering environmental factors (Lv et al., 2020). Additionally, it has been suggested that vitamin D deficiency may act as a suppressor of gene expression. One of the key genes suppressed under vitamin D deficiency is the tyrosine hydroxylase (TH) gene, which plays a crucial role in the regulation of dopamine biosynthesis and the expression of neurotrophic factors (Zhou et al., 2019). In conclusion, the FokI (C/T) polymorphism has been reported to be significantly associated with PD, and its presence may influence the risk, severity, and cognitive function of Parkinson's patients, as well as the effectiveness of vitamin D3 supplementation in these individuals (Lv et al., 2020).

10. Vitamin D Supplementation in Parkinson's Disease

Low vitamin D levels are frequently observed in patients with Parkinson's disease (PD) (Evatt et al., 2008; Evatt et al., 2011; Ding et al., 2013), which has been associated with inadequate intake of vitamin D and various micronutrients (Barichella et al., 2022). Only a limited number of studies have investigated the effects of vitamin D supplementation on PD risk and disease progression. Some studies have demonstrated that vitamin D supplementation and outdoor work significantly reduce the risk of developing Parkinson's disease (Kwon et al., 2013). In a randomized, placebo-controlled study that examined the effects of 1200 IU/day vitamin D supplementation for 12 months in patients with Parkinson's disease, serum vitamin D levels were reported to have doubled in the supplemented group, whereas no increase was observed in the placebo group. Additionally, while no change in motor severity was reported in the supplementation group, deterioration was observed in the control group (Suzuki et al., 2013). In another study that evaluated the effects of 1000 IU/day vitamin D supplementation or placebo in 120 Parkinson's patients, no changes in dyskinesia or motor severity were observed after three months (Habibi et al., 2018). A study aiming to assess the effects of high-dose vitamin D (10,000 IU/day) for 16 weeks on balance in Parkinson's patients using the Sensory Organization Test found no overall improvement in balance; however, it was reported that vitamin D had an effect on balance in the younger subset of the group (mean age: 60 years) (Hiller et al., 2018). Additionally, vitamin D supplementation has been observed to reduce camptocormia in Parkinson's patients (Sato et

al., 2011). In a randomized controlled trial investigating vitamin D supplementation, vitamin D3 was found to temporarily delay PD progression in patients with the FokI CT and TT genotypes (Suzuki et al., 2013). The administration of 1200 IU/day vitamin D supplementation for 12 months (Suzuki et al., 2013) or 10,000 IU/day for 16 weeks (Hiller et al., 2018) did not lead to adverse effects such as hypercalcemia. Thus, vitamin D supplementation appears to be a promising approach in Parkinson's disease; however, the dose of vitamin D that may induce toxicity remains uncertain (Lv et al., 2020).

11. Conclusion and Recommendations

Serum vitamin D levels have been consistently reported to be lower in individuals with Parkinson's disease (PD). Higher concentrations of vitamin D have been associated with reduced disease risk and severity, as well as improved cognitive function and psychological well-being. However, upon examination of the current literature, it is evident that findings regarding the preventive or therapeutic efficacy of vitamin D supplementation in PD remain inconsistent. Therefore, insufficient evidence currently exists to support the routine use of vitamin D as a standard adjunctive treatment in clinical practice. These conflicting results are thought to arise from variations in the methods used to measure vitamin D, as well as the application of different threshold values across studies. Additionally, environmental factors such as geographic location, sunlight exposure, dietary habits, physical activity levels, and socioeconomic conditions are considered to significantly influence outcomes and limit the generalizability of findings. Genetic factors are also believed to play a critical role in this association. Specifically, polymorphisms in the vitamin D receptor (VDR) gene may affect both the susceptibility to PD and the individual response to vitamin D supplementation. This suggests that the relationship between vitamin D and PD may be modulated by personalized biological mechanisms, thereby highlighting the importance of incorporating genetic profiling into future investigations. In order to clarify the potential role of vitamin D in the pathophysiology and clinical progression of PD, there is a need for large-scale, multicenter, randomized controlled trials. Such studies should systematically assess a range of parameters, including serum 25(OH)D levels, motor symptom severity, non-motor symptoms (e.g., cognitive impairment, depression, and sleep disturbances), quality of life, disease progression rates, and potential adverse effects. Furthermore, classification of patients according to disease stage and clinical phenotype is essential for obtaining more specific and clinically relevant results. In conclusion, although an increasing body of evidence suggests a potential role for vitamin D in the pathogenesis and symptomatology of Parkinson's disease, the inconsistency of findings precludes definitive recommendations at this time. Further high-quality research is warranted to elucidate underlying mechanisms and to inform evidence-based clinical decision-making regarding the use of vitamin D in PD management.

Declaration of Competing Interest

The authors declare that they have no financial or non-financial competing interests.

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Author's Contributions

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D. Önay Derin (0000-0003-0624-5714): *Supervision / Advising, Analysis and Interpretation, Critical Review*

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Lyophilization and Sensory Analysis of Traditional Artisan Turkish Cheeses

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Abstract

Türkiye boasts a rich cheese culture, shaped by its diverse geographical features and climatic conditions. Currently, 40 types of cheese in Türkiye have received geographical indication status, contributing to both the local economy and gastronomic tourism. This study aims to dry artisan Turkish cheeses using the lyophilization (freeze-drying) method, which is intended to improve shelf life, ease packaging and transport, and enable snack-type consumption while preserving nutritional value. To achieve this, Ezine, Kars Kaşar, Kars Gruyère, Smoked Circassian, and Divle Obruk Tulum cheeses were freeze-dried at -70°C for 24 hours using a lyophilization device. Following the drying process, the sensory properties of the cheeses were evaluated by 10 trained panelists based on attributes, such as color, odor, texture, crispness, aroma, mouthfeel, and overall acceptability. According to the results, all cheese samples received above-average scores (mean ± SD): Ezine: 4.50 ± 1.27; Smoked cheese: 4.50 ± 0.71; Kars Kaşar: 4.60 ± 0.70; Kars Gruyère: 4.09 ± 0.94; Divle Obruk: 4.82 ± 0.40. The findings obtained in this study indicated that consuming cheese in an alternative form is feasible. It was observed that the cheeses retained their color, taste, shape, and aroma, and their potential to return to their original state upon rehydration was also evaluated. This alternative form may contribute to the promotion of traditional Turkish products and increase appeal among younger generations. Further studies focusing on packaging and rehydration can be conducted for commercialization efforts in the future.

Keywords: Lyophilization, Cheese, Freeze-drying, Artisan, Geographical Indication.

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1. Introduction

Milk has long been a fundamental component of human nutrition. This is primarily because milk and dairy products contain energy, macronutrients, and a variety of micronutrients such as proteins, carbohydrates, fats, minerals, and vitamins. One of these dairy products is cheese. Cheese production is based on the coagulation of casein, the main milk protein, through the use of enzymes or starter cultures. During this process, whey is removed and the curd solidifies, forming the desired texture. Starter cultures accelerate and control the fermentation process, ensuring that the final product attains the intended characteristics (Hastaoğlu et al., 2021).

Cheese can be classified according to several factors, including the type of coagulant used, ripening conditions, fat and moisture content, and the applied heat treatment method. Beyond its sensory qualities such as flavor and aroma, cheese also offers several health benefits. For instance, due to the presence of lactic acid bacteria, particularly probiotic strains, it exhibits angiotensin-converting enzyme (ACE) inhibitory properties (Kamath et al., 2021). Conjugated linoleic acid (CLA) and phytanic acid, both found in cheese, are two fatty acids known for their positive effects on health. The protein content of cheese can vary between 3% and 40%, depending on the type. During production, the breakdown of proteins leads to the formation of peptides with known biological activities such as antihypertensive, antioxidant, and anti-inflammatory effects. Cheese is also rich in vitamins A, riboflavin, and B12. Its high fat content makes it a suitable vehicle for vitamin D supplementation. Additionally, cheese is a significant source of calcium and contains other essential minerals such as iron, zinc, and selenium (Callaghan et al., 2017).

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Several studies have shown that probiotic microorganisms, which are found in high concentrations in cheese, positively influence flavor and aroma while also shortening the ripening period. This offers significant economic advantages. Fermented milk beverages and yogurt are prominent in the development of probiotic dairy products, yet they are limited by their short shelf lives. In contrast, the longer shelf life and ripening period of cheese make it a more advantageous carrier in this context. The physicochemical properties of cheese provide a favorable environment for probiotics, allowing them to survive longer during both production and storage compared to other dairy products. These advantages are associated with factors such as the fat content, pH level, storage conditions, and low oxygen environment of cheese.

As a concentrated and nutritious food, cheese contains higher levels of fat, protein, and minerals compared to milk, and it is also more easily digestible. The proteins in cheese have high biological value, thereby enhancing its nutritional quality. These proteins possess superior nutritional value compared to plant-based proteins and provide a well-balanced source of essential amino acids required by the human body (Özbay & Tüysüz, 2024).

The term 'artisan' refers to products made with specialized manual techniques, often by individual craftsmen. In the context of cheese, this term evokes traditional Turkish varieties such as Divle Obruk and Kars Gruyère, which are recognized internationally for their distinct qualities (Negizözen & Yılmaz, 2020). This study aims to apply the lyophilization (freeze-drying) method to artisan Turkish cheeses in order to extend their shelf life and contribute to product diversity in the field of gastronomy.

2. Conceptual Framework

Cheese is believed to have originated approximately 8,000 years ago in the "Fertile Crescent" region, located between the Tigris and Euphrates rivers in present-day Iraq. With the advent of the Agricultural Revolution, the domestication of plants and animals began, and humans quickly recognized the nutritional potential of milk produced by domesticated animals. However, milk not only served as a valuable nutritional resource but also provided an ideal medium for bacterial growth. Certain bacteria used the lactose in milk as an energy source, producing lactic acid in the process; under hot and dry climatic conditions, this created favorable conditions for early forms of milk preservation, including spontaneous fermentation and primitive drying techniques. When sufficient acid was produced, caseins, the main proteins in milk, coagulated at their isoelectric point, forming a gel, which led to the accidental emergence of the first fermented dairy products (Fox, 1993). Although this topic is not known yet, it is widely accepted that cheese was first made in Mesopotamia. The word for cheese was incorporated into the Turkish language with the migration of Turks to Anatolia (Bekiroğlu, 2019).

Although cheese production methods vary from region to region, the basic process involves the coagulation of casein through the use of enzymes or starter cultures (microbial cultures added to initiate fermentation with desired characteristics). During this process, the resulting whey is separated, and the remaining curd is compressed to form the desired structure. Key factors that differentiate cheese types include the use and characteristics of starter cultures, ripening conditions, milk composition, and the diet of the animals. As a result, each region has developed its own distinctive cheese varieties.

2.1. Cheese in Türkiye

Türkiye is one of the notable countries in cheese production, thanks to its diverse climatic conditions, vegetation, and geographical landscape. The country spans a wide range of climatic conditions, from the humid climate of the Black Sea region in the north to the high mountains in the east. These differences are reflected in the composition and nutritional value of the milk used in cheese production, as well as in the flavor profiles of the cheeses. Nearly every region in Türkiye produces its own varieties of cheese using distinct techniques. Güzeler and Yıldırım (2016) reported the presence of a large variety of local cheese types in Türkiye. However, despite this rich cheese heritage, many traditional varieties are still produced and promoted only within limited regions. In this context, five artisan cheeses, Ezine, Kars Kaşar, Kars Gruyère, Smoked Circassian, and Divle Obruk, stand out as traditional varieties at risk of being forgotten in the face of industrialization and technological advancement.

Geographical indication (GI) practices have emerged as an important mechanism for protecting local products and enhancing their value. A GI safeguards the unique characteristics of a product that are specific to a particular geographical area and emphasizes its distinctive qualities derived from regional knowledge, traditional production techniques, and cultural heritage. In Türkiye, the registration of geographical indications is overseen by the Turkish Patent and Trademark Office (TürkPatent), a process

initiated with the enactment of Decree Law No. 555 in 1995. As of 2024, a total of 932 products have been registered with geographical indications in Türkiye, 40 of which are cheeses (TürkPatent, 2024). While some of these cheeses, such as Ezine, Erzincan Tulum, and Kars Kaşar, are well known and widely consumed across the country, others are produced and consumed only in specific regions (Güzeler & Koboyeva, 2020). Geographical indication status enables the protection of these products, prevents counterfeiting, and facilitates their promotion based on their authentic qualities.

In addition to the legal protection they provide, geographical indications (GIs) also carry significant economic and touristic value. The registration of GI products has led to revitalization in local economies and increased support for regional producers. Furthermore, GI-certified products can contribute to regional development by becoming focal points of tourism. For example, cheese producers in countries such as France and Italy have positioned their GI-labeled cheeses as attractions not only for local consumers but also for tourists, thereby securing a strong presence in the global market (Anonymous, 2015). Türkiye holds similar potential and is emerging as an important destination in the field of gastronomic tourism through its GI-certified cheese varieties. Notably, Edirne white cheese produced in the Thrace region, Ezine cheese from the Marmara region, and Erzincan Tulum cheese from Eastern Anatolia are among the GI-labeled products that attract attention within the scope of gastronomy tourism (Küpelikılınç, 2020).

The development of gastronomy tourism presents a significant opportunity for promoting Türkiye's rich diversity of local cheeses. Tourists who travel to experience regional flavors also engage with the cultural fabric of the area, thereby enriching their overall experience. Gastronomy tourism not only offers a taste-centered journey but also supports the preservation and sustainability of cultural heritage. Türkiye's cheese diversity is being introduced to broader audiences through geographical indication schemes, contributing to both national recognition and economic development. In addition to revitalizing local economies, GI-certified cheeses also have the potential to enhance the global visibility of Turkish cheese varieties (Hastaoğlu et al., 2021). As of now, a total of 40 cheeses have been registered in Türkiye by TürkPatent, including 15 as designation of origin (one of which is registered internationally) and 25 as geographical indication of source (Table 1).

2.1.1. Ezine Cheese

White cheese is the most widely produced and consumed cheese type in Türkiye and also holds the highest economic value. Although it can be produced in nearly all regions of the country, it is especially common in Thrace, Marmara, Aegean, and Central Anatolia. Ezine cheese, in particular, is a well-known and widely preferred white cheese that is produced on a large scale in Türkiye. This cheese is made from the milk of animals that graze within the geographically defined northern and western zones of the Kaz Mountains, where they feed on endemic plants such as marjoram, savory, sage, hairy mint, and thyme. Its production requires a specific milk mixture consisting of at least 40% goat's milk, 35–45% sheep's milk, and no more than 25% cow's milk. Ezine cheese has a pale yellowish-white color, medium firmness, and a non-brittle texture with few and small holes. It is classified as full-fat brined white cheese (Çakmakçı & Salık, 2021).

The production of Ezine cheese begins with pasteurizing the mixed milk—composed of goat, sheep, and cow milk in specific ratios—at 60–70 °C for 30 minutes. After pasteurization, the milk is coagulated using rennet derived from calf stomachs at a temperature of 30–35 °C. Once the curd forms, it is cut to separate the whey. The curd is then placed into special cheese molds lined with cheesecloth, and pressure is applied to accelerate the drainage process. After being cut into blocks, the curds are placed in brine containing sea salt until the desired flavor and aroma are developed. The cheeses are then removed from the brine and arranged in a single layer inside metal tins. Dry salt is sprinkled on top, and the cheeses are left to rest for 10–12 hours. After this resting phase, the excess liquid is removed, and the tins are sealed airtight with added brine (Ilgar, 2019).

The milk used in Ezine cheese production comes from specific breeds of animals. These include Holstein (Black and White) dairy cows; Sakız, Dalgıç, Tahirova, and Sakız-Dalgıç crossbred sheep; and Karakeçi (hair goat) and Turkish Saanen goats. The milk from these selected breeds plays a crucial role in creating the distinctive taste and quality of Ezine cheese. Similar cheeses with comparable characteristics are produced in other countries under different names—for instance, Bjalo Salamureno Sirene in Bulgaria, Feta in Greece, Domiati in Egypt, and Telemea in Romania. Each of these reflects the cultural heritage of its respective region through unique production techniques and flavor profiles (Özbay & Tüysüz, 2024). Ezine cheese has a creamy flavor derived from milk fat and a cooked

Table 1. List of geographically indicated cheeses registered in Türkiye

Cheese Name	App. Date	Regist. Number	Regist. Date	Registration Type	Province
Antakya Carra	19.07.2019	679	18.02.2021	Designation of Origin	Hatay
Antakya Künefelik	28.08.2018	979	22.12.2021	Geographical Indication	Hatay
Antep Cheese / Gaziantep	20.04.2017	356	04.06.2018	Geographical Indication	Gaziantep
Atlantı Dededağ Tulum	02.04.2021	1327	26.01.2023	Geographical Indication	Konya
Ağrı Tulum Cheese	05.11.2021	1565	29.03.2024	Geographical Indication	Ağrı
Bergama Tulum	15.01.2020	1597	06.06.2024	Geographical Indication	İzmir
Diyarbakır Örgü	15.02.2010	170	22.02.2013	Geographical Indication	Diyarbakır
Edirne White	10.05.2004	93	23.10.2007	Designation of Origin	Edirne
Elbistan Kelle	16.06.2023	1500	22.11.2023	Geographical Indication	Kahramanmaraş
Erzincan Tulum	21.08.2000	30	29.08.2001	Designation of Origin	Erzincan
Erzurum Civil	17.12.2007	116	11.09.2009	Geographical Indication	Erzurum
Erzurum Moldy Civil	01.03.2010	164	30.11.2012	Geographical Indication	Erzurum
Ezine	24.02.2006	86	10.04.2007	Designation of Origin	Çanakkale
Gümüşhane Deleme	14.03.2018	694	17.03.2021	Geographical Indication	Gümüşhane
Hanak String	08.04.2020	1563	08.04.2024	Designation of Origin	Ardahan
Karaman Divle Obruğu Tulum	16.06.2015	270	08.12.2017	Designation of Origin	Karaman
Kargı Tulum	08.08.2018	933	26.10.2021	Designation of Origin	Çorum
Kars Kaşar	14.02.2014	190	12.10.2015	Designation of Origin	Kars
Kars Gruyere	24.09.2021	1640	17.09.2024	Geographical Indication	Kars
Kırklareli White	06.07.2018	636	23.12.2020	Designation of Origin	Kırklareli
Kırklareli Aged Kashar	05.02.2022	1408	11.07.2023	Designation of Origin	Kırklareli
Malatya Cheese	28.10.2020	1164	06.07.2022	Geographical Indication	Malatya
Malkara Aged Kashar	14.09.2010	261	06.12.2017	Designation of Origin	Tekirdağ
Manyas Kelle	12.09.2019	628	16.12.2020	Geographical Indication	Balıkesir
Maraş Parmak / Sıkma	19.09.2016	727	17.04.2021	Geographical Indication	Kahramanmaraş
Mengen	13.11.2018	1482	06.10.2023	Geographical Indication	Bolu
Pınarbaşı Uzunyayla Circassian	06.02.2020	724	14.04.2021	Designation of Origin	Kayseri
Sakarya Abkhaz	02.07.2020	746	03.05.2021	Geographical Indication	Sakarya
Savaştepe Mihaliç Kelle	29.11.2022	1405	10.07.2023	Geographical Indication	Balıkesir
Talas Çörek Otlu Çömlek	23.11.2022	1560	12.03.2024	Geographical Indication	Kayseri
Urfa Cheese / Şanlıurfa	01.10.2018	807	27.07.2021	Geographical Indication	Şanlıurfa
Vakfıkebir Külek	25.06.2018	764	25.05.2021	Geographical Indication	Trabzon
Van Herb	28.07.2017	405	31.12.2018	Designation of Origin	Van
Yozgat Çanak (Bowl)	14.03.2011	281	18.12.2017	Geographical Indication	Yozgat
Yüksekova Çirek	11.02.2020	1086	18.04.2022	Geographical Indication	Hakkâri
Çankırı Küpecik	29.12.2017	907	01.10.2021	Geographical Indication	Çankırı
Çayeli Koloti	20.11.2020	1199	24.08.2022	Designation of Origin	Rize
İvrindi Kelle	16.02.2021	1025	09.02.2022	Geographical Indication	Balıkesir
İzmir Tulum	15.06.2010	1006	24.01.2022	Geographical Indication	İzmir

milk aroma resulting from heat treatment. The use of sea salt in its production prevents the cheese from melting and disintegrating, while also facilitating the release of moisture during maturation. Additionally, the cheese is produced exclusively with natural rennet (Subaşı, 2021).

2.1.2. Kars Kaşar Cheese

Kaşar cheese, known for its sliceable and semi-hard texture, belongs to the pasta filata cheese group. The defining characteristic of this group is that the curd is kneaded after reaching a specific level of acidity by immersing it in hot water. There are various theories regarding the origin of the name “Kaşar.” One suggests that it derives from the Latin word coerceo, meaning "to press under pressure," referring to the squeezing of whey from the curd. Another theory traces it to the Hebrew word kasher (kosher), indicating food that is religiously permissible for Jewish people. It is believed that Kaşar cheese was first produced in Thessaloniki by a Jewish woman, and its origin may be linked to the Balkans and Italy. Larger and harder versions of Kaşar are referred to as Caciocavallo in Italy. Similar cheeses are found under different names in other countries: Kaskaval in Bulgaria, Kačkavalj in the former Yugoslavia, Caşcaval in Romania, Kasseri in Greece, Kaskaval in Hungary, Kavkazskij syr in Russia, and Rumi in Egypt. Additionally, Italy's Provolone and Mozzarella, France’s Fromage à pâte filée, and England’s Cheddar also share similarities with Kaşar in terms of production techniques (Aydemir, 2010).

Kaşar cheese began to be produced by Turks after their migration to Anatolia. Traditionally, the highest quality Kaşar is made from sheep's milk, although today it is commonly produced using a mixture of cow and sheep milk. In some regions, goat milk is also included. Kaşar cheeses produced in Eastern Anatolia are generally smaller in size, weighing around 6 kilograms, while those produced in the Thrace region are larger, typically weighing between 11 and 12 kilograms (Üçüncü, 2004, as cited in Aydemir, 2010).

The production of Kaşar cheese in Kars dates back to the early years of the Turkish Republic. It was first produced in 1926 in the village of Kümbetli by workers under Filibeli Fehmi Bey and Süleyman Bey. The milk is filtered through several layers of cloth immediately after milking and then transported to the production facility. Its temperature is adjusted to 27–33 °C, and a commercial rennet is added to initiate coagulation. After gentle stirring, the curd is covered with cheesecloth. Coagulation takes 40–90 minutes, after which the curd is cut into rice-sized pieces. After resting for 5–10 minutes, a cheesecloth is placed over the vat, and the whey is drained. The remaining curd is transferred to straining cloths, tied at four corners, and hung from a rod to drain. The bundle is then pressed between wooden boards for 3–4 hours. The curd is reshaped into squares and left under pressure for another 3–8 hours in rooms kept at 16–25 °C. After pressing, the curd is removed from the cloth, cut into large pieces, and left to ferment. Completion of fermentation is determined by testing whether the curd becomes pliable and sticks together when placed in hot water. Once this condition is met, the curd is considered ready for kneading. The fermented curd is placed into perforated metal baskets and boiled for 2–3 minutes in 75 °C water containing 5% salt. The cheese is stirred with wooden paddles to remove excess water, then kneaded and folded by hand on the processing table. Air bubbles are pressed out manually, and the cheese is shaped into loaves. A technique called “belly tying” is applied, where the base of each cheese is twisted and pinched off using thumbs. The formed cheeses are placed into molds while still warm and pierced with metal rods to release trapped moisture. They are flipped regularly until cooled, then kept in the molds for one more day. After unmolding, they are moved to a salting room, where coarse salt is applied for two days, and the cheeses are turned frequently to facilitate maturation (Aydemir, 2010).

2.1.3. Kars Gruyère Cheese

Gruyère cheese is a European-origin variety that holds a notable economic and cultural place among Türkiye’s domestically produced cheeses. With increasing domestic demand, both its production and import have been rising steadily each year. It is primarily produced in large quantities in the Eastern Anatolia Region, especially in and around the province of Kars. It is known that Gruyère was introduced to Kars through the Russians, who also taught the local population how to produce it (Ulutaş et al., 1993). The first Gruyère cheese production facility in Anatolia was established in the village of Boğatepe by a Swiss cheesemaker who had settled there. Subsequently, Swiss and German cheese experts brought in by the Russians trained the local people in cheese-making, leading to the establishment of numerous production sites throughout the Kars–Ardahan region. After the Bolshevik Revolution in 1917 and the withdrawal of the Russian army, many of these skilled individuals emigrated, posing a risk to the continuity of local Gruyère-making knowledge. However, ethnic groups such as the Kıçak, Karapapak, and Karakalpak, who

fled the Russian occupation and settled in the Ardahan–Kars area, were able to continue production using their previous experience and training they received from local Malakans, thereby preserving this tradition to the present day (Arınç, 2018).

Kars Gruyère cheese closely resembles Swiss Emmental in terms of hardness, production method, and technology used. Its name is derived from the town of Gruyères in the Swiss canton of Fribourg. While Germans and Swiss call it "Greyezer," the cheese is referred to as "Gravyer" in Türkiye, "Groyer" in Austria, "Graviera" in Greece, "Grojer" in Yugoslavia and Poland, and "Perniön Gruyere" in Finland. Gruyère is known for its complex production process and is among the high-nutritional-value cheeses that undergo one year of maturation. In Boğatepe village, around 18,000 liters of milk are collected during the lactation season, with approximately 10,000 liters allocated for Gruyère production. Since it takes about 17 kg of milk to produce 1 kg of Gruyère, over half a ton of cheese is produced daily in Boğatepe. The distinctive flavor and color of Kars Gruyère come from the milk of Zavot cows, a breed whose milk contains about 4% fat, contributing to the cheese's signature yellow hue and aromatic flavor. The production process of Gruyère cheese differs significantly from that of Kaşar cheese, as it involves longer kneading, greater milk quantity, and more extended brining durations (Derinalp-Çanakçı, 2020). In the initial step, milk is heated to 34–35 °C and coagulated using natural rennet. After about 45 minutes, the resulting curd is cut into rice-sized particles using wooden cutters and left to rest for approximately 10 minutes. The curd is then stirred and cooked at 57 °C for 40–45 minutes. It is transferred to double-layered cheesecloths and pressed with applied weight. The pressing stage continues with the cheeses resting for 24 hours. After this, the top and bottom surfaces of the cheeses are salted and left for one day. This is followed by five days of dry salting and 5–7 days of brine salting.

The maturation process begins with the cheeses being placed on wooden shelves in sauna-like rooms maintained at 28–32 °C and 85–90% humidity for 3 to 4 weeks. During this phase, "eye" formation (holes) and internal swelling are observed. Finally, the cheeses are ripened at 12–13 °C for 90–150 days. Kars Gruyère can be stored and consumed for more than three years (Güzeler & Koboyeva, 2020).

2.1.4. Smoked Circassian (İsli Çerkes) Cheese

Circassian cheese is traditionally produced by Circassian families in regions of Anatolia where Circassian communities are densely populated, such as Sinop, Düzce, Bolu, Sakarya, Balıkesir, Bursa, Çanakkale, Biga, Hendek, and Gönen. It is also produced in the ancestral lands of Circassians in the Caucasus. Circassian cheese is also believed to be produced in countries with Circassian communities, such as Syria, Jordan, and Israel. Although there is no precise historical documentation on the origin of Circassian cheese, it is estimated to have been produced for at least 150 years. In the past, Circassian families commonly made their own cheeses at home; however, due to changing social conditions over the last 20–25 years, home-based cheese production has declined (Ayar et al., 2015).

Traditional Circassian cheese is usually made from the milk of cows and sheep raised by the families themselves. Because production takes place at the household level, large pots called şuvan are commonly used to heat the milk. In some villages, about 5–6 liters of milk are heated to boiling and then cooled to the proper temperature for coagulation. In other areas, a spoon or ladle of rennet is added as the milk begins to boil, and the milk continues to simmer briefly. The rennet used may be previously soured whey, tart yogurt whey, or commercial rennet. Once added to the milk, the mixture is not stirred, and curdling occurs within a short time. To facilitate curd formation, a small amount of citric acid dissolved in water is sometimes added. When coagulation is complete, lumps form on the surface and the whey becomes clear. At this stage, the curd is scooped out with a perforated ladle and placed into baskets made from woven willow branches, typically 30 cm in diameter and 5–10 cm in height. Alternatively, a portion of the whey may be removed with a ladle, and the basket is dipped directly into the pot to collect the curd. The curd is left in the basket overnight to drain and take shape. The next day, salt is applied first to one side, then the other. On the third day, the cheese is washed with cold water and made ready for fresh consumption (Aydınol, 2010). The cheese is then stored in a cool place for several days to allow the outer surface to harden and form a rind. Traditionally, this cheese was dried in the fireplaces of village homes, but today it is produced in specially designed processing rooms. The cheese is not exposed directly to flame; rather, it is placed on racks and wrapped in cloth, positioned in the hottest part of the smoke, and left to mature until the desired level of smokiness is achieved. The type of wood used in the smoking process is critical: smoke from dry mulberry and acacia wood creates the optimal environment for flavoring the cheese (Turkiye Kültür Portalı, n.d.).

2.1.5. Divle Obruk Tulum Cheese

Divle Obruk tulum cheese is produced in the village of Üç Harman, located in the Ayrancı district of Karaman province in Türkiye. The cheese takes its name from the Divle Obruk (a karstic cave), where it is aged and acquires its unique characteristics. Entirely indigenous to this region, the cheese owes its distinctive features to the specific environmental and geographical conditions of the area (Toklu & Pekerşen, 2019). The curd, made from a mixture of goat's milk (10%), cow's milk (10%), and predominantly sheep's milk (80%) sourced from animals grazing on highland pastures and meadows, is packed into tulums (traditional bags) made from goat or lamb skin. The cheese is then aged in the Divle Obruk cave for five to six months before it becomes ready for consumption. During the periods when animals cannot graze, they are fed with roughage such as dried alfalfa or straw. This special feeding and production method contributes to the cheese's characteristic taste and texture (Çakmakçı & Salık, 2021).

Tulum cheese is generally made from raw milk and matured over a period of 3 to 7 months in caves, cellars, or specially controlled storage environments. The texture of Divle tulum cheese is non-porous, with a sharp odor and a pungent, slightly acrid flavor. The full-fat curd, derived from sheep's milk, is tightly packed into airtight sheep or goat skins. Initially, the cheeses are wrapped in cloth and dried in a cool environment for 9–10 days before the tulums are sealed. For maturation, the tulums are transferred to the Divle cave. They are carefully placed on sloped surfaces to prevent contact with one another. With over 300 years of history, the Divle Obruk cave possesses a unique karstic structure that plays a crucial role in the cheese's maturation. Within this environment, the cheese ages at a stable temperature of 4–5 °C and 80% humidity. The outer surface of the cheese, in contact with the skin, turns a dirty gray, while the interior remains cream or porcelain white. Approximately one month after being placed in the cave, natural molds in blue, white, and red hues begin to grow on the cheese surface. These molds typically dry out by September or October, and as the cheese continues to mature, the red mold layer naturally begins to peel away. This distinctive process contributes to the cheese's complex aroma and texture (Toklu & Pekerşen, 2019).

2.2. Lyophilization (Freeze-Drying)

Lyophilization is a stabilization technique in which substances are first frozen and then subjected to sublimation and desorption processes to reduce the solvent content to a minimum, thereby preventing biological or chemical reactions. This method, which combines cryopreservation and freeze-drying technologies, enables long-term storage of substances. Lyophilization is commonly used for preserving biological materials, allowing products to remain dry and biologically active, resulting in extended shelf life and easy rehydration (Karagül & Altuntaş, 2018).

Today, freeze-drying is widely employed in the food and pharmaceutical industries (e.g., vaccines, proteins, peptides, colloidal carriers, etc.) for drying high-value products and improving their stability, despite its high cost and energy consumption. One of the main reasons for preferring this method in food processing is its ability to produce high-quality products with excellent rehydration properties and prolonged shelf life (Özdemir, 2021). Water in products can exist either in a free form or bound to the matrix through various interactions. While free water freezes at 0 °C, bound water does not behave in the same manner. The objective of freeze-drying is to remove all ice (frozen water) and a certain amount of bound water. This is a multi-stage and complex process. The freezing phase of the product usually takes place under atmospheric pressure. The primary drying phase (actual lyophilization) involves the sublimation of ice into vapor under low pressure. The secondary drying phase aims to reduce the residual moisture content of the product to the desired final level (Nowak & Jakubczyk, 2020).

Historically, lyophilization dates back to ancient times. The Aztecs and Eskimos used this method to preserve food. Similarly, the Incas applied the same principle for drying meat under the low-oxygen atmospheric conditions and sunlight exposure of the Altiplano plains in the Andes Mountains centuries ago. Toward the end of the 1880s, the technique began to be tested in laboratory settings, and its fundamental principles were gradually understood. By 1890, it was reported that tissues could be dried at approximately –20 °C and subatmospheric pressure. In 1905, researchers demonstrated that animal tissues could be dried under a pressure 1 atm lower by using a chemical pump. However, lyophilization only began to see practical application in the 1930s, when it became necessary to process heat-sensitive antibiotics and blood products (Karagül & Altuntaş, 2018).

Freeze-drying consists of three fundamental stages: initial freezing (solidification), primary drying (sublimation of ice), and secondary drying (desorption of unfrozen water) (Özdemir, 2021).

2.2.1. Freezing

Among all stages of lyophilization, the freezing phase is the most critical. This step prevents structural collapse, foaming, and shrinkage of the product. It also helps maintain the physical appearance, solubility, and essential characteristics of the material, while minimizing temperature-sensitive reactions. For optimal pre-freezing, both the solvent (water) and solutes in the solution must be fully crystallized. Crystallization determines the microstructure of the product during the freezing stage. Reaching a suitable freezing temperature aligned with the chemical nature of the substance is essential. The freezing temperature and the final temperature of the material directly affect the quality of the dried product. Rapid freezing promotes the formation of small ice crystals. The higher the density of these crystals, the better the preservation of the product structure. Successfully completing the freezing stage ensures a high-quality final product (Ergün, 2015).

2.2.2. Primary Drying

After freezing, the condenser is cooled and the system temperature must be below –60 °C (Cevher, 2016). The pressure inside the freeze-dryer chamber is reduced via vacuum pumps. In pharmaceutical applications, depending on the target product temperature and container system, chamber pressure is typically maintained between 30 and 300 mTorr. For sublimation to occur and for water vapor to reach the condenser, the chamber pressure must remain below the vapor pressure of the ice on the sublimation surface. When this condition is met, sublimation begins: ice in the outermost frozen layers directly converts to vapor. Among the most crucial variables in lyophilization, product temperature—especially at the sublimation surface—is key. Lower product temperatures and the corresponding low vapor pressure of ice can significantly prolong drying. Research shows that a mere 1 °C increase in product temperature can shorten the primary drying time by approximately 13% (Gaidhani et al., 2015).

During primary drying, vapor generated from ice sublimation and bound water desorption travels through the porous structure of the frozen matrix and is removed via the vacuum system. The water vapor condenses and accumulates as ice on the condenser surface. Once all the frozen water has been removed from the product, the primary drying phase is considered complete (Sadıkoğlu & Özdemir, 2003).

2.2.3. Secondary Drying

Even after primary drying, water molecules may remain adsorbed on the product surface. Although the product may appear dry, its residual moisture content can still exceed 7–8%, which is insufficient to ensure long-term stability of most biological materials. Therefore, a secondary drying phase is implemented to further reduce moisture content without compromising product stability.

Secondary drying reduces residual water while maintaining the cake structure and desired product quality (Ergün, 2015). Unlike primary drying, where low shelf temperatures and moderate vacuum are used, secondary drying is achieved by increasing shelf temperature while minimizing chamber pressure to facilitate desorption. However, shelf temperatures must not be raised excessively, as high temperatures can cause protein polymerization or degradation of biological components. The duration of secondary drying is typically one-third to one-half of the primary drying phase. During this phase, since no ice remains and risks such as “melting traces” are eliminated, the product can withstand higher heat exposure. However, the remaining water is more tightly bound to the matrix, requiring more energy for removal. Traditionally, maximum vacuum levels are employed to enhance desorption (Gaidhani et al., 2015). For temperature-sensitive products, shelf temperatures between 10–35 °C are commonly used, whereas for less sensitive products, 50 °C and above may be applied. By the end of secondary drying, the product’s final moisture content, storage conditions, and duration directly affect its quality. For example, some products retain quality for extended periods at –20 °C, but may degrade within a year if stored at 37 °C (Sadıkoğlu & Özdemir, 2003).

2.3. Lyophilization in Cheese Drying: Technological and Functional Approaches

Ferreira et al. (2017) studied Marajó cheese, developed from raw buffalo milk in the Amazon region of Brazil, using two different drying techniques: spray drying and freeze-drying. The aim of the study was to develop a probiotic starter culture using both drying methods. The results showed that spray-dried samples exhibited higher survival rates and better technological performance. Cultures preserved via spray drying retained approximately 10^9 CFU/g after 60 days at 4 °C, while those subjected to freeze-drying dropped to around 10^7 CFU/g.

Büyüksırıt-Bedir and Kuleaşan (2019) freeze-dried White, Kaşar, and Tulum cheeses and analyzed them. On the first day, physicochemical properties of the samples were examined to establish baseline quality characteristics. White cheese had the highest moisture and salt content, while Tulum cheese stood out with the

highest titratable acidity and fat content. The freeze-dried samples were stored at room temperature for six months, and microbial populations were monitored. Results indicated that Tulum cheese generally had higher microbial counts. The total bacterial count in Tulum was 7.71 ± 0.10 log CFU/g, compared to 5.70 ± 0.07 log CFU/g in White cheese.

Köprüalan et al. (2020) experimentally studied low-fat white cheese dried using three different methods: hot air drying (at 50, 60, and 70 °C with 1.8 m/s airflow), microwave drying (180, 360, 540 W), and freeze-drying (0.2, 0.15, 0.1 mbar). The drying rate of white cheese increased with higher drying temperature, microwave power, and reduced vacuum pressure, thereby shortening the drying time. Measurements of parameters such as temperature, pressure, time, weight, and power were recorded for all three methods. Freeze-drying required slightly less time compared to hot air drying.

Cao et al. (2024) tracked the development of cheese made from pasteurized milk and used lyophilization to dry the cheese samples. Differential scanning calorimetry (DSC), water activity, and moisture content measurements were performed on the dried samples to assess thermal and hygroscopic behavior.

Takma et al. (2024) produced a dried white cheese powder using freeze-drying, incorporating whey protein isolate (WPI) and carboxymethyl cellulose (CMC), and used it in bread formulations. Bread quality characteristics were evaluated by replacing wheat flour with 10%, 15%, and 20% cheese powder. CMC-containing powders were found to reduce water activity, thus potentially contributing to quality preservation during shelf life. The texture properties of bread were significantly affected by the level of cheese powder. The study concluded that white cheese nearing its expiration date could be converted into powder via freeze-drying and repurposed in the food industry as a sustainable, value-added product.

Golzarijalal et al. (2024) employed freeze-drying to preserve the functionality of mozzarella cheese. Six mozzarella samples differing in block size and composition were analyzed both experimentally and numerically during freezing and thawing. A numerical model based on the enthalpy method was developed to solve heat and mass transfer equations. Reducing the NaCl content from 1.34% to 0.07% significantly shifted the phase change temperature from ~4.5 °C to −3 °C. Simulation results showed minimal salt migration in free moisture at a depth of 1–2 cm during freezing, while an 8–10% increase in salt concentration was observed at the block center. A response surface methodology (RSM) was used to generate a predictive model capable of estimating freezing and thawing times under varying block sizes and processing conditions. The RSM model indicated that increased salt content extended freezing time but shortened thawing time.

2. Material and Methods

3.1. Materials

The production sites where the cheeses were manufactured in accordance with traditional methods were identified, and the cheeses were procured from selected appropriate locations (Figure 1). The experimental procedures of this study were approved by the Social Sciences Ethics Committee of Başkent University (Approval No: E-52056571-605.99-224222, Date: 14.04.2023).

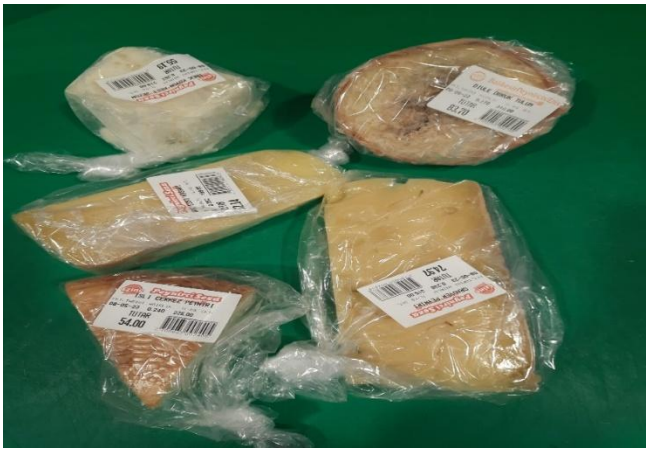

Figure 1. Images of the artisan cheeses procured from the market

The differences in moisture content among the cheeses were taken into consideration, and cutting techniques were applied accordingly. Multiple rounds of drying were performed in an effort to achieve optimal results. Except for Ezine cheese, all other cheeses were grated using a regular or mandoline grater. Since Ezine cheese is more susceptible to crumbling, it was cut into cubes of approximately 5 mm.

3.2. Freeze-drying procedure

After an initial 24-hour freezing process at –18 °C, the cheese samples were freeze-dried for 24 hours at –70 °C under vacuum using a freeze-dryer (Teknosem, Toros TRS 4-4 model, Türkiye). The drying procedure was repeated when necessary, based on the quality of the final product.

3.3. Sensory analysis

In this study, an experimental research method was employed. Five types of artisan cheeses dried using the lyophilization method were evaluated through sensory analysis by a panel of 10 trained panelists. The panel size and sample number required for the sensory evaluation and consumer preference testing were determined based on the study by Altuğ-Onoğur and Elmacı (2019). The panelists were asked to rate the cheese samples based on the following criteria: color, odor, texture, cheese crispness, aroma and flavor characteristics, mouthfeel, difference from the original form, and overall assessment, using a scale from 1 (very poor) to 5 (very good). The collected data were analyzed by calculating means and standard deviations, and the results were visualized using a radar chart.

3. Results and Discussion

The appearance of the freeze-dried cheese samples is presented in Figure 2.

Ezine Cheese | Kars Kaşar Cheese

Divle Obruk Tulum | Kars Gruyère

Smoked Circassian

Figure 2. Individual views of the cheeses after freeze-drying

Due to its composition containing three types of milk and a relatively high moisture content, Ezine cheese took longer to dry compared to the other cheese samples. In panelist evaluations, it generally received high scores for color and odor, but was perceived as noticeably different from its original form. The low mouthfeel score was interpreted by some panelists as a result of moisture loss during drying and the lower fat content of goat's milk. Another panelist noted that the removal of moisture actually enhanced the aroma of the cheese. The radar chart representing the sensory evaluation results for Ezine cheese is presented in Figure 3.

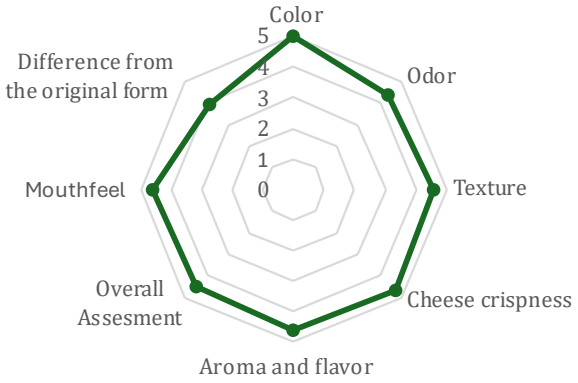

Figure 3. Radar Chart of the Sensory Evaluation for Ezine Cheese

When evaluated in terms of quality criteria, the smoked cheese generally received high scores from the panelists. However, one panelist stated that the original structure of the cheese had deteriorated and, considering the other criteria as well, reported a low overall preference. The radar chart representing the sensory evaluation of the smoked cheese is presented in Figure 4.

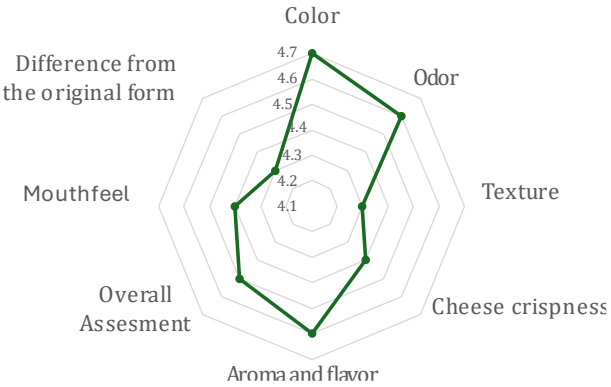

Figure 4. Radar Chart of the Sensory Evaluation for Smoked Cheese

Due to its low moisture content and high fat content, Kars Kaşar cheese achieved the desired level of crispness and a strong aroma. No significant color deterioration was observed following the drying process. Panelists and practitioners considered it a favorable option for introducing a healthy snack and an artisan cheese to households in an alternative form. The radar chart representing the sensory evaluation of Kars Kaşar cheese is shown in Figure 5.

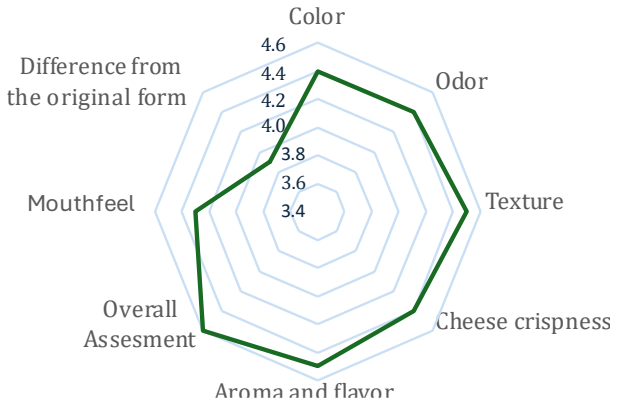

Figure 5. Radar Chart of the Sensory Evaluation for Kars Kaşar Cheese

Kars Gruyère, known for its long and labor-intensive production process, is one of Türkiye's strongly flavored cheeses with limited production and consumption due to factors such as modernization and industrialization. After the drying process, its color slightly lightened and, due to the shape of the cuts, it was sometimes mistaken for Kars Kaşar. Its characteristic holes also disappeared. Panelists noted that the already intense flavor of the Gruyère became even more concentrated with the loss of moisture, which altered its original character. One panelist remarked that the crispness found in Kaşar was lacking, and two other panelists gave it lower scores for overall acceptability. The radar chart representing the sensory evaluation of Kars Gruyère is presented in Figure 6.

When evaluated based on quality criteria, Divle Obruk cheese received high scores compared to the other four cheeses. The lowest score was given by one panelist for texture, while two panelists rated it lower in terms of difference from the original form. One panelist suggested that the cheese might taste even better if processed with additional aromatic ingredients. Due to seasonal limitations in production and the extended ripening period required for this cheese, freeze-drying presents a promising solution for making it available year-round. It also offers potential as a domestic alternative to imported cheeses. As a product carrying local and cultural significance, Divle Obruk cheese has the potential to remain present on tables for longer periods and to gain wider recognition in the field of gastronomy. The radar chart of the sensory evaluation results for Divle Obruk cheese is presented in Figure 7.

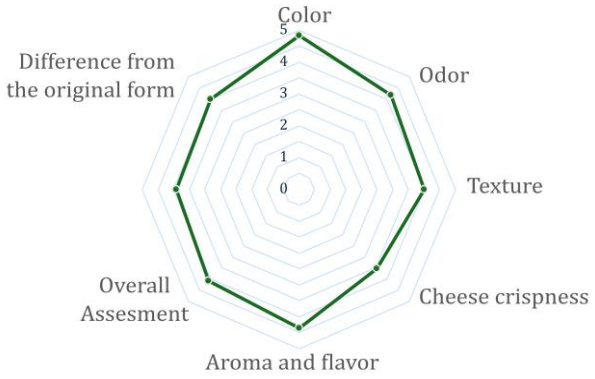

Figure 6. Radar Chart of the Sensory Evaluation for Kars Gruyère Cheese

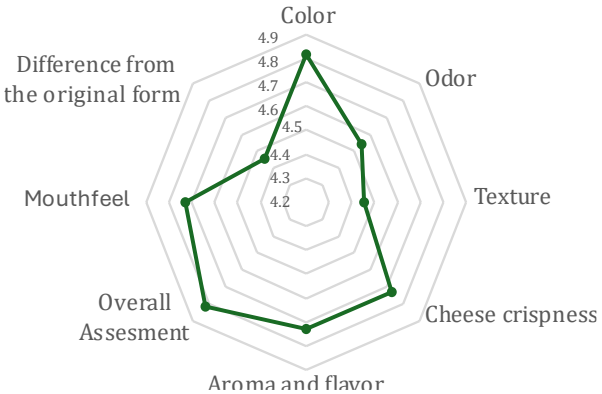

Figure 7. Radar Chart of the Sensory Evaluation for Divle Obruk Cheese

*All sensory attributes were evaluated on a 5-point scale (1 = very poor / least desirable, 5 = very good / most desirable).

Based on these results, all cheese samples received above-average scores in sensory evaluation. These findings indicate that if properly introduced to the market, such cheese products may be well-received by consumers and generate demand.

In their study on low-fat white cheese, Köprüalan et al. (2022) investigated the application of freeze-drying and microwave drying under various conditions prior to explosion puffing drying. The aim was to determine the most suitable processing parameters among alternative drying techniques. Their findings indicated that the dried cheese possessed high sensory quality and could be considered a nutritious snack product.

Table 2. Sensory Evaluation Results of the Cheeses

Sensorial Properties	*Ezine Cheese*	*Smoked Circassian Cheese*	*Kars Kaşar Cheese*	*Kars Gruyère Cheese*	*Divle Obruk Tulum Cheese*
Color	5.00±0.00	4.70±0.48	4.40±0.84	4.82±0.40	4.82±0.40
Odor	4.40±0.97	4.60±0.70	4.40±0.84	4.18±1.08	4.55±1.04
Texture	4.60±0.70	4.30±1.06	4.50±0.71	4.00±1.18	4.45±1.04
Cheese Crispness	4.70±0.48	4.40±0.52	4.40±0.52	3.55±0.69	4.73±0.47
Aroma–Flavor Characteristics	4.60±0.97	4.60±0.70	4.50±0.71	4.36±0.81	4.73±0.47
Overall Acceptability	4.50±1.27	4.50±0.71	4.60±0.70	4.09±0.94	4.82±0.40
Mouthfeel	4.60±0.70	4.40±0.70	4.30±1.06	3.91±0.94	4.73±0.65
Difference from Original	3.99±0.99	4.30±0.95	3.90±0.88	4.00±1.10	4.45±0.82

The results obtained in the present study are consistent with the existing literature, similarly demonstrating that traditional artisan Turkish cheeses exhibit high sensory characteristics.

Koca et al. (2015) reported that the drying temperature significantly affects the drying characteristics of white cheese. In the present study, freeze-drying was applied under specific conditions. Considering that the effectiveness of food processing methods largely depends on the processing parameters and equipment used, it is reasonable to assume that variations in drying conditions would influence both the final product quality and sensory perceptions. Nonetheless, the results presented in Table 2 indicate that the cheeses achieved high levels of sensory acceptability. This suggests that further optimization of drying parameters could potentially lead to even better outcomes.

4. Conclusions

According to the results, Ezine cheese dried more slowly than the other samples due to its composition of three different types of milk and higher moisture content. In panel evaluations, it received generally high scores for color and odor but was perceived as noticeably different from its original form. Divle Obruk cheese received the highest overall scores among the five samples when evaluated based on quality criteria. The smoked cheese was also rated highly in most categories. Kars Kaşar achieved the desired crispness and strong aroma, attributed to its low moisture content and high fat level. Kars Gruyère, which has a long and labor-intensive production process, is a strongly flavored cheese produced and consumed in limited regions due to factors such as modernization and industrialization. After the drying process, a slight lightening in color and the loss of its characteristic holes were observed. Panelists noted that the already intense flavor of Gruyère became even more concentrated with moisture loss. Overall, all cheeses received above-average scores from the panelists (lowest = 4.09 ± 0.94; highest = 4.82 ± 0.40). These findings indicate that it is feasible to consume cheese in an alternative form. If marketed appropriately, such products may attract consumer demand. A limitation of this study is that the products were not packaged. Future studies should explore packaging methods and evaluate the potential for rehydration before consumption.

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Declaration of Competing Interest

The authors declare that they have no financial or non-financial competing interests.

Author's Contributions

E. Yıldırım (0009-0009-7640-2341): *Data Curation, Investigation, Formal Analysis, Methodology, Writing, Review & Editing*.
C.C. Yalçıner (0009-0000-6436-2279): *Data Curation, Investigation, Formal Analysis, Methodology, Writing, Review & Editing*
İ. Yılmaz (0000-0001-5938-3112): *Data Curation, Investigation, Formal Analysis, Methodology, Writing, Review & Editing*

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Evaluation of Nutrition Software Used in Türkiye: A Comparison of CeviCal and BeBIS with TürKomp

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Abstract

This study aims to compare the food information programs used in Türkiye, CeviCal and BeBİS, and evaluate how they differ from TürKomp. Data on food consumption records, consumption frequency, and anthropometric measurements of healthy individuals obtained from previous studies were entered into the CeviCal, BeBİS and TürKomp programs. Energy and nutritional values were analyzed to compare these two programs using TürKomp as the reference standard. According to the food consumption record data entered, there was no significant difference in carbohydrate and fat percentages among the three programs ($p>0.05$), while significant differences were found in other nutrients ($p<0.05$). No difference was found between TürKomp and CeviCal in the values of macronutrients, such as energy, carbohydrate, protein and fat ($p>0.05$). A significant and high-level positive correlation was found between TürKomp and both CeviCal and BeBİS in energy, protein and carbohydrate values. According to food consumption frequency data, there was no significant difference in energy, protein and fat percentage between TürKomp and CeviCal ($p>0.05$), while a significant difference was found with BeBİS ($p<0.05$). A high level of positive correlation was found between TürKomp and CeviCal in terms of energy, protein, carbohydrate and fat values. However, a moderate level of positive correlation was found between TürKomp and BeBIS. When BeBİS and CeviCal programs used in Türkiye were compared to TürKomp, CeviCal gave more consistent results in carbohydrate, protein and fat values. There were similarities and differences between the three programs in terms of other nutrients. However, larger studies comparing data from all programs are needed to support the current findings.

Keywords: Nutrient analysis, Nutrition information programs, Food consumption, Food consumption frequency survey.

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1. Introduction

Nutrition is the process of consuming and utilizing food substances to sustain life and maintain health (Özer & Tekinşen, 2021). Ongoing research explores the relationship between nutrient content, intake levels, physiological functions, and overall health maintenance (Council, 2006). The specific combinations of macronutrients that effectively optimize health remain uncertain. The World Health Organization (WHO) has published a booklet outlining the recommended intake levels for certain nutrients (World Health Organization, 2019). Many countries also conduct national dietary studies to assess macronutrient distribution and disseminate findings to the public (Trumbo et al., 2002).

Food composition databases have been developed to identify the nutrient content of foods and make this information accessible to the public (U.S. Department of Agriculture [USDA], 2019). Similarly, TürKomp (Turkish Food Composition Database) has been developed in our country. TürKomp includes the nutrient components of numerous processed and unprocessed agricultural products (TürKomp, 2015).

In dietary practice, exchange lists have been developed to facilitate the practical substitution of foods with similar nutritional compositions (Usman, 1973). The increasing number of studies in nutrition and the establishment of comprehensive food composition databases have created a need for developing more specific dietary plans and for their effective monitoring. Food composition software programs are utilized in academic research to analyze survey data collected for assessing individuals' dietary habits (Yeung, 2023).

CeviCal is a web-based application that enables remote monitoring of patients' daily physical activity

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levels, medication use, and dietary intake records. In addition, it provides a comprehensive nutritional assessment by analyzing the energy and macro- and micronutrient contents of the recorded foods (Cesur, 2024a; Cesur & Genç, 2024).

BeBIS, which has been extensively utilized and widely recognized in Türkiye over the years, is a conventional nutrition software that operates via a local driver and does not require an internet connection, making it suitable primarily for expert users (Cesur et al., 2022).

This study aims to compare the nutrition information software programs widely used in Türkiye—CeviCal and BeBIS—and to assess their discrepancies in reference to the Turkish Food Composition Database (TürKomp).

2. Material and Methods

2.1. Type, Aim, and Study Sample

This study employed a comparative research design. It was planned to compare the BeBIS and CeviCal dietary assessment programs using TürKomp as the reference database. Accordingly, differences between the two programs were evaluated using dietary records and food frequency data obtained from previous studies for which ethical approvals had been granted. CEBEBİS and CeviCal use the same nutritional database.

This study compiled dietary record questionnaires, food frequency forms, and anthropometric measurements from 400 participants aged 18 and above derived from earlier research. Surveys with incomplete or incorrect information were identified by the researchers, and these participants were excluded from this study; therefore, these data were not entered into the nutrient analysis programs. As a result, dietary records of 338 participants and food frequency data of 370 participants were transferred into the programs for analysis.

2.2. Data Collection

Study Data: The data used in this study included information obtained from dietary record questionnaires and food frequency forms collected in previous research.

Dietary Records: The dietary records utilized in this study were collected by documenting all foods consumed over two consecutive weekdays and one weekend day. This method was chosen because it is more effective in identifying individuals' general dietary habits (Cesur, 2024b; Cesur et al., 2023; Cesur & Öztürk Kara, 2024). These three-day dietary records were divided by three to calculate the average daily energy and nutrient intakes.

Food Frequency: The food frequency questionnaire is tailored for specific research objectives and is used to assess individuals' nutritional status (Cesur, 2024b; Cesur et al., 2023; Cesur & Öztürk Kara, 2024). In this study, a food frequency questionnaire consisting of 45 food items and six frequency options was used. As a result, the average daily intake of energy and nutrients was calculated based on the participants' reported food consumption frequencies.

Incomplete and inconsistent data entries were excluded from the analysis. No imputation method was employed. Only complete cases were analyzed to preserve the accuracy of inter-program comparisons in this study.

2.3. Data Processing

Each participant's dietary intake record, food consumption frequency, and anthropometric measurements were entered into the programs as individual cases. The input data were transferred to Microsoft Excel. Nutrient information from the TürKomp database was also saved in Microsoft Excel.

For the nutrient analysis programs (BeBIS and CeviCal), the collected three-day dietary intake records were processed through the programs and then exported to Microsoft Excel. To obtain the average daily energy and nutrient values, the total amounts were divided by three. Food consumption frequency data were recorded by noting the portion sizes consumed from the food groups on the form and transferring them to Microsoft Excel.

Cooking losses were calculated using standardized loss percentages provided in the TÜBER database. For example, common cooking methods, such as boiling and grilling, were applied with their corresponding nutrient loss ratios to convert raw food values to cooked equivalents.

TürKomp is a national database developed through advanced laboratory analyses to determine the compositional values of foods produced and consumed in Türkiye (TürKomp, 2015). Accordingly, TürKomp served as the reference to evaluate the differences between the two nutrition software programs. Since TürKomp does not provide a system for direct data entry, a customized Excel format was developed to enable the analysis of dietary intake data. In this format, the cooked forms of foods listed as raw in the TürKomp database were calculated using the cooking loss percentages provided by TÜBER (Turkish Food Composition and Cooking Loss Database) as a reference. For each food item, standard portion sizes

and cooking method-specific loss rates were taken into account to convert raw amounts into cooked equivalents, thereby allowing for a more accurate analysis of dietary intake. Additionally, recipes that were reported in the dietary records but not available in TürKomp were identified, formulated, and added to the Excel format. Dietary intake data were entered for three consecutive days, and the total intake was divided by three to calculate the daily average energy and nutrient values. To allow for the inclusion of food frequency data, a food frequency questionnaire was developed using the food items and food groups available in TürKomp in accordance with standard survey formats. Portion sizes consumed were recorded based on reported frequencies, and daily average energy and nutrient values were calculated accordingly. Due to the large sample size, a G*Power analysis was conducted, and each sample group was randomly selected to include 68 healthy individuals. The power analysis was performed using G*Power software (version 3.1.9.4). The effect size (f) was set at 0.25 (medium effect), $\alpha = 0.05$, and 1-β (power) = 0.90, resulting in a required sample size of 68 participants for each comparison group.

2.4. Statistical Analysis

Statistical analyses were performed using RStudio software version 0.98.501, developed with the R programming language. Non-parametric methods were preferred since the data did not follow a normal distribution based on the Kolmogorov–Smirnov and Shapiro–Wilk tests. Therefore, the Wilcoxon Signed-Rank Test and Friedman Test were used instead of paired t-tests and repeated measures ANOVA. Continuous variables were presented as mean ± standard deviation (SD), while categorical variables were expressed as counts and percentages. When data did not follow a normal distribution, the Wilcoxon Signed-Rank Test was applied for dependent groups, for comparisons involving three related groups, the Friedman Variance Analysis was used. A p-value below 0.05 was considered statistically significant. G-Power software version 3.1.9.4 was also employed to determine the required sample size. Bonferroni correction was applied to p-values derived from post hoc pairwise tests to reduce the probability of Type I error resulting from multiple comparisons.

2.5. Ethics Approval

The data obtained from previous studies for which ethical approval was obtained were entered into these three programs. Ethics committee decisions are stated respectively. It was obtained from the Avrasya University Ethics Committee on 29.06.2021 with the decision numbered E-69268593-050-4141 and from the Avrasya University Ethics Committee on 02.12.2022 with the decision numbered E-69268593-050-16127.

3. Results

Analysis of dietary intake records from 338 healthy individuals showed that 239 were female (70.7%) and 61 were male (18%). Demographic data indicated a mean age of 24.52 ± 5.10 years, a mean height of 164.12 ± 7.77 cm, and a mean body weight of 62.61 ± 13.82 kg. The mean Body Mass Index (BMI) was calculated as 23.17 kg/m². Based on G-power analysis, the selected sample of 68 healthy individuals included 52 females (76.5%) and 16 males (23.5%), with a mean age of 23.97 ± 4.19 years, mean height of 165.10 ± 6.84 cm, and mean body weight of 61.72 ± 12.84 kg.

In this study, dietary intake records of 338 healthy individuals were entered into the CeviCal and BeBIS programs, and nutrient components were compared between these two software. Evaluations revealed no significant difference in fat percentage ($p > 0.05$), whereas significant differences were found in all other nutrient components ($p < 0.05$) (Table 1).

Dietary intake records of 68 healthy individuals were entered into the CeviCal, BeBIS, and TürKomp programs. No significant differences were in portion sizes were observed among the three software platforms. Additionally, no significant differences were observed in the percentages of carbohydrates and fats among the nutrient components ($p > 0.05$). While no significant differences were detected between TürKomp and CeviCal for macronutrients, including energy, carbohydrate, protein, and fat, as well as micronutrients, such as vitamin C, vitamin A, and eicosapentaenoic acid (EPA) ($p > 0.05$), significant differences were found between BeBIS and both TürKomp and CeviCal ($p < 0.05$). No significant differences were noted between BeBIS and TürKomp for vitamin B6 and vitamin E values ($p > 0.05$), whereas significant differences existed between CeviCal and TürKomp ($p < 0.05$) (Table 2).

When the programs were normalized on a gram basis, and nutrient contents per 100 grams were examined, no significant differences were found among the three programs for carbohydrate, protein, and fat percentages ($p > 0.05$). Furthermore, no significant differences were identified between TürKomp and CeviCal for carbohydrate, protein, and fat values ($p > 0.05$); however, significant differences were observed between BeBIS and CeviCal, as well as between BeBIS and TürKomp for these nutrients ($p < 0.05$) (Table 2).

Table 1. Analysis of dietary intake records using CeviCal and BeBIS programs

	CeviCal (n=338)			*BEBİS (n=338)*			*p*
	Mean	*Min.*	*Max.*	*Mean*	*Min.*	*Max.*	
Energy (kcal)	146.88	46.74	287.48	113.70	39.35	240.93	< 0.001
CHO (g)	15.54	1.66	38.29	11.33	2.48	24.67	< 0.001
CHO (%)	4.86	1.30	18.23	4.51	0.97	21.76	< 0.001
Protein (g)	6.43	2.37	11.57	4.80	1.16	10.82	< 0.001
Protein %	2.11	0.43	7.88	2.00	0.39	8.53	< 0.001
Fat (g)	6.56	2.15	13.58	5.31	0.71	13.55	< 0.001
Fat %	4.79	1.23	14.93	4.79	0.73	17.49	0.127
Dietary Fiber (g)	1.09	0.00	4.23	0.97	0.00	3.37	< 0.001
Cholesterol (g)	16.75	0.00	80.62	26.90	0.41	107.02	< 0.001
PUFA (g)	0.50	0.00	2.04	0.94	0.18	4.81	< 0.001
SFA (g)	1.45	0.15	5.04	2.15	0.18	6.85	< 0.001
MUFA (g)	0.81	0.00	3.29	1.79	0.20	5.82	< 0.001

PUFA: Polyunsaturated Fatty Acids, SFA: Saturated Fatty Acids, MUFA: Monounsaturated Fatty Acids

A significant and strong positive correlation was found between TürKomp and both CeviCal and BeBIS for energy, protein, and carbohydrate values. For fat values, a strong positive correlation was observed between TürKomp and CeviCal, while a moderate positive correlation was identified between TürKomp and BeBIS (Figure 1).

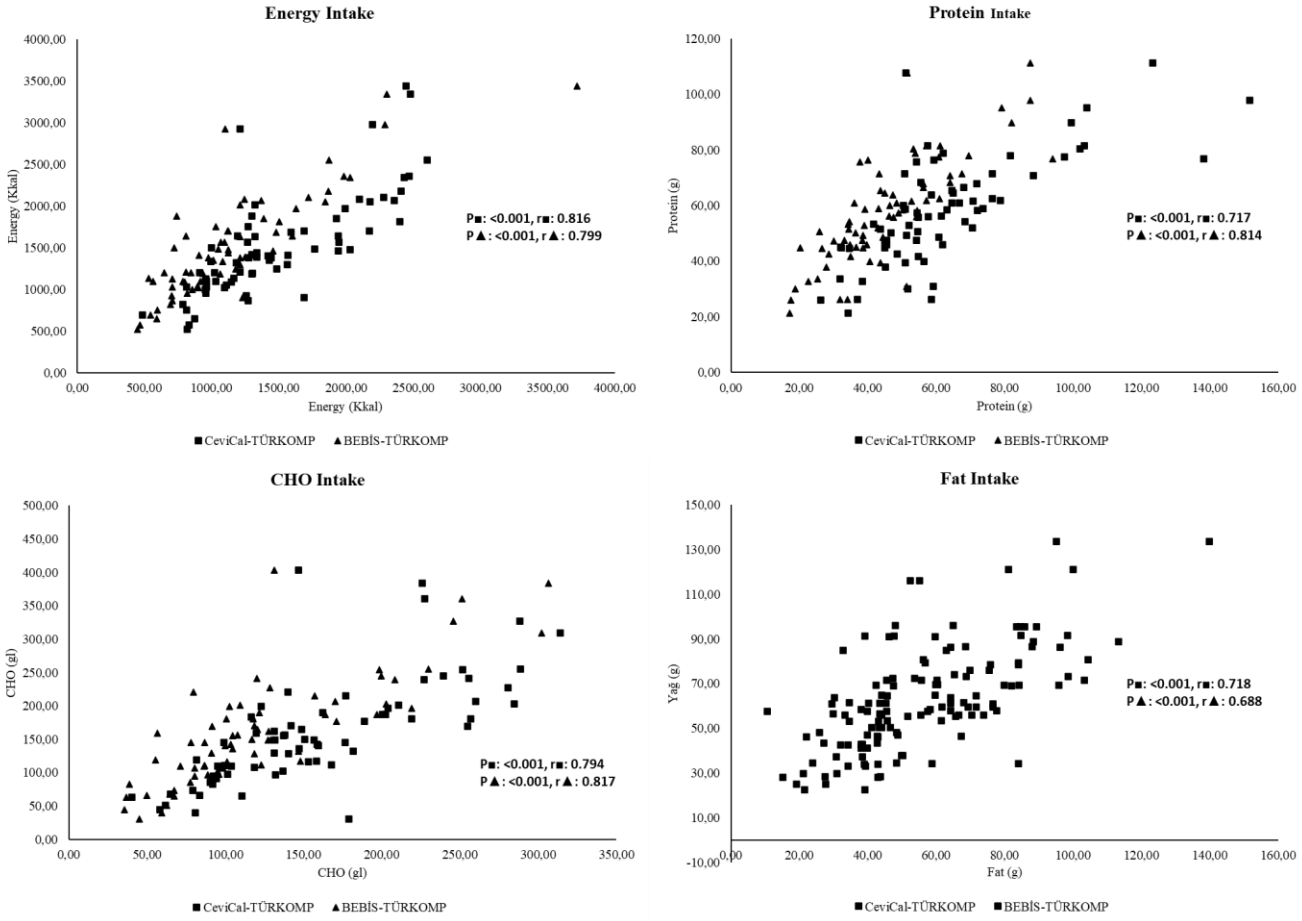

Figure 1. Correlation of dietary intake records with energy, protein, carbohydrate, and fat values

Table 2. Analysis of dietary intake records using CeviCal, BeBIS, and TürKomp programs

	CeviCal (n=68)			BEBİS (n=68)			Türkomp (n=68)			p	p1	p2	p3
	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.				
Amount (g)	1019.68	581.00	2252.00	1032.11	500.67	2432.00	1057.42	504.33	2472.00	0.053			
Energy (Kcal)	1474.95	485.72	2603.04	1150.32	449.00	3717.23	1508.17	526.42	3439.01	**< 0.001**	**< 0.001**	0.668	**< 0.001**
CHO (g)	158.42	40.25	314.17	120.44	35.37	306.47	159.11	30.73	402.99	**< 0.001**	**< 0.001**	0.510	**< 0.001**
CHO (%)	42.49	24.80	56.60	41.72	23.16	64.95	41.41	14.18	57.18	0.291			
Protein (g)	62.63	26.24	151.60	45.75	17.07	94.07	58.07	21.25	111.23	**< 0.001**	**< 0.001**	0.215	**< 0.001**
Protein%	17.45	9.22	30.76	16.64	9.41	26.74	16.11	9.19	27.13	**0.011**	0.310	**0.008**	0.510
Fat (g)	64.85	19.23	139.85	49.91	10.67	100.30	64.39	22.66	167.14	**< 0.001**	**< 0.001**	0.607	**< 0.001**
Fat (%)	39.81	25.68	59.66	39.88	13.27	60.15	39.20	23.43	71.92	0.662			
Posa (g)	11.19	1.07	48.13	10.01	1.07	26.39	19.07	5.14	44.74	**< 0.001**	0.391	**< 0.001**	**< 0.001**
PUFA (g)	4.76	0.13	17.03	8.69	2.10	26.50	6.45	1.44	20.58	**< 0.001**	**< 0.001**	0.119	**< 0.001**
SFA (g)	14.78	3.80	46.17	20.23	2.63	41.27	19.55	5.43	53.38	**< 0.001**	**< 0.001**	**0.006**	0.368
MUFA (g)	7.79	0.82	34.14	17.07	2.73	35.37	17.04	6.41	39.91	**< 0.001**	**< 0.001**	**< 0.001**	0.795
Na (mg)	1320.86	145.52	5981.62	2318.65	704.67	6303.40	2585.28	771.87	6397.02	**< 0.001**	**< 0.001**	**< 0.001**	0.595
Vitamin B2 (mg)	0.57	0.03	2.24	0.85	0.20	2.90	0.66	0.24	1.77	**< 0.001**	**< 0.001**	**0.006**	**< 0.001**
Vitamin B6 (mg)	0.49	0.02	1.92	0.88	0.31	2.81	0.85	0.31	1.97	**< 0.001**	**< 0.001**	**< 0.001**	0.864
Vitamin C (mg)	40.13	0.70	159.60	65.33	12.23	525.50	44.32	0.44	197.64	**< 0.001**	**< 0.001**	0.435	**< 0.001**
Vitamin A (µg)	397.05	0.00	4611.36	594.16	96.67	2111.33	264.34	53.91	880.21	**< 0.001**	**< 0.001**	0.346	**< 0.001**
Vitamin E (mg)	3.91	0.00	16.23	6.85	1.70	19.57	7.85	0.62	25.66	**< 0.001**	**< 0.001**	**< 0.001**	0.932
EPA (g)	0.00	0.00	0.29	0.45	0.00	1.57	0.07	0.00	1.09	**< 0.001**	**< 0.001**	0.096	**< 0.001**
ALA (g)	0.22	0.00	1.34	4.97	0.23	20.53	0.38	0.03	1.67	**< 0.001**	**< 0.001**	**0.049**	**< 0.001**
Per 100 g													
Energy (Kcal)	144.73	60.34	216.71	109.81	63.96	198.30	142.37	78.48	236.63	**< 0.001**	**< 0.001**	0.797	**< 0.001**
CHO (g)	15.50	5.00	25.02	11.49	3.79	20.44	14.88	3.63	25.97	**< 0.001**	**< 0.001**	0.510	**< 0.001**
CHO (%)	4.46	1.48	7.83	4.38	0.97	10.56	4.24	0.92	9.50	0.065			
Protein (g)	6.22	2.84	10.01	4.51	2.00	8.19	5.65	2.95	9.93	**< 0.001**	**< 0.001**	0.510	**< 0.001**
Protein%	1.87	0.49	3.94	1.80	0.39	4.12	1.71	0.46	3.96	0.110			
Fat (g)	6.41	2.39	12.27	4.85	1.14	9.49	6.18	3.12	13.43	**< 0.001**	**< 0.001**	0.966	**< 0.001**
Fat (%)	4.23	1.38	7.58	4.22	0.98	7.37	4.11	0.97	9.55	0.416			
Posa (g)	1.13	0.13	4.23	1.00	0.13	2.16	1.83	0.94	3.65	**< 0.001**	0.284	**< 0.001**	**< 0.001**
PUFA (g)	0.49	0.01	1.91	0.85	0.27	2.65	0.64	0.14	2.07	**< 0.001**	**< 0.001**	0.096	**< 0.001**
SFA (g)	1.46	0.47	4.05	1.95	0.28	4.35	1.90	0.73	5.87	**< 0.001**	**< 0.001**	**0.005**	0.178
MUFA (g)	0.80	0.10	3.00	1.66	0.29	3.21	1.66	0.75	4.01	**< 0.001**	**< 0.001**	**< 0.001**	0.607
Na (mg)	126.02	16.89	373.87	226.31	75.15	535.60	252.47	89.23	733.15	**< 0.001**	**< 0.001**	**< 0.001**	0.215
Vitamin B2 (mg)	0.06	0.00	0.26	0.09	0.02	0.36	0.06	0.03	0.15	**< 0.001**	**< 0.001**	0.062	**< 0.001**
Vitamin B6 (mg)	0.05	0.00	0.23	0.09	0.03	0.20	0.08	0.02	0.16	**< 0.001**	**< 0.001**	**< 0.001**	0.932
Vitamin C (mg)	3.95	0.11	12.88	6.23	1.10	35.04	4.24	0.03	13.17	**< 0.001**	**< 0.001**	0.999	**< 0.001**
Vitamin A (µg)	40.32	0.00	532.08	60.32	9.11	168.72	25.85	6.44	109.94	**< 0.001**	**< 0.001**	0.310	**< 0.001**
Vitamin E (mg)	0.39	0.00	1.27	0.68	0.21	1.60	0.77	0.07	2.58	**< 0.001**	**< 0.001**	**< 0.001**	0.668
EPA (g)	0.00	0.00	0.04	0.04	0.00	0.13	0.01	0.00	0.14	**< 0.001**	**< 0.001**	0.851	**< 0.001**
ALA (g)	0.02	0.00	0.11	0.46	0.03	1.49	0.04	0.01	0.15	**< 0.001**	**< 0.001**	0.062	**< 0.001**

PUFA: Polyunsaturated Fatty Acid, SFA: Saturated Fatty Acids, MUFA: Total Monounsaturated Fatty Acids, EPA: Eicosapentaenoic Acid, ALA: Alpha-Linolenic Acid, Note: p^1 = comparison between CeviCal and BeBIS; p^2 = comparison between TürKomp and CeviCal; p^3 = comparison between TürKomp and BeBIS. Decimal points are standardized using dots.

Dietary intake frequencies of 370 healthy individuals were entered into the CeviCal and BeBIS programs. When nutrient components were compared between the two programs, no significant difference was found in carbohydrate percentage ($p > 0.05$), whereas significant differences were observed for all other nutrients ($p < 0.05$). When dietary intake frequencies of 68 healthy individuals were analyzed across CeviCal, BeBIS, and TürKomp, significant differences were found among all nutrient components between the three programs ($p < 0.05$). No significant differences were detected between TürKomp and CeviCal for energy, protein, and fat percentage values ($p > 0.05$), while significant differences existed between BeBIS and these two programs ($p < 0.05$). No significant differences were found between TürKomp and BeBIS for total polyunsaturated and monounsaturated fatty acid values ($p > 0.05$) (Table 3).

A strong positive correlation was found between TürKomp and CeviCal for energy, protein, carbohydrate, and fat values. However, a moderate positive correlation was observed between TürKomp and BeBIS (Figure 2).

4. Discussion

This study used previously collected dietary records with ethical approval to compare two nutrient analysis software programs widely used in Türkiye (CeviCal and BeBIS) . While the focus was primarily on macronutrients, further exploration of micronutrient profiles, including validation through biochemical markers, is warranted. Specifically, the bioavailability of micronutrients, such as vitamins B2, B6, and E, should be considered in further research. The study population primarily comprised healthy young adults (mean age 24.52 ± 5.10 years), which may limit the generalisability of the findings to other age groups or individuals with chronic health conditions.

TürKomp, the Turkish Food Composition Database, was served as the reference standard to assess the consistency and accuracy of the results (Caferoglu et al., 2019; WHO, 2018).

The concept of "ideal nutrition" is a multidimensional phenomenon that varies from society to society and is influenced by various factors, such as health status, age, and ethnicity (Townsend et al., 2023; Venn, 2020). Studies show that nutrition literacy and portion control education have positive effects on individuals' nutritional behaviors (Ertürk Yaşar, 2023). Moreover, comprehensive and up-to-date food composition databases are critically important for both individual dietary assessments and public health policies. Additionally, it has been emphasized that such databases should be further developed as they enhance public awareness and benefit society (Delgado et al., 2021).

Nutrient analysis software is widely utilized in academic research and clinical practice (Caferoglu et al., 2019). However, in this study, significant differences were identified in the nutrient estimates generated by CeviCal and BeBIS. For example, while vitamin C values were similar between CeviCal and TürKomp, BeBIS estimated this value considerably higher. Similarly, vitamin B2 levels calculated based on standardized 100-gram portions were significantly higher in BeBIS than both CeviCal and TürKomp. In addition, vitamin B6 intake derived from dietary records appeared consistent between BeBIS and TürKomp.

Table 3. Analysis of dietary intake frequencies using CeviCal and BeBIS, and CeviCal, BeBIS, and TürKomp programs

	CeviCal (n=370)			**BEBİS (n=370)**				**CeviCal (n=68)**			**BEBİS (n=68)**			**Türkomp (n=68)**						
	Mean	*Min*	*Max*	*Mean*	*Min*	*Max*	*p*	*Mean*	*Min*	*Max*	*Mean*	*Min*	*Max*	*Mean*	*Min*	*Max*	*P value*	*P¹*	*p²*	*p³*
Energy (kcal)	2102.63	453.58	11154.06	1731.05	424.20	8196.30	**<0.05**	1939.09	453.58	11154.06	1637.11	424.20	8196.30	1926.03	541.24	11075.11	**<0.05**	**<0.05**	>0.05	**<0.05**
CHO (g)	236.75	44.33	1614.34	193.05	42.30	1189.30	**<0.05**	206.78	44.33	1614.34	175.14	42.30	1189.30	187.25	44.54	1423.67	**<0.05**	>0.05	**<0.05**	**<0.05**
CHO (%)	43.97	23.09	78.64	43.93	22.21	105.49	>0.05	41.54	24.64	60.86	41.47	23.54	58.18	37.35	15.97	58.79	**<0.05**	>0.05	**<0.05**	**<0.05**
Protein (g)	73.22	12.33	284.56	65.90	8.40	289.40	**<0.05**	62.80	15.38	284.56	61.18	14.20	289.40	64.70	16.75	200.20	**<0.05**	**<0.05**	**<0.05**	**<0.05**
Protein %	14.32	5.49	28.89	15.27	5.69	40.97	**<0.05**	13.84	8.07	23.57	15.16	9.11	40.97	14.30	7.00	28.63	**<0.05**	**<0.05**	>0.05	**<0.05**
Fat (g)	96.34	22.33	413.54	77.10	16.30	287.70	**<0.05**	94.25	23.87	413.54	75.54	21.60	249.40	95.24	26.15	638.37	**<0.05**	>0.05	**<0.05**	**<0.05**
Fat %	41.85	7.95	65.03	40.37	13.54	70.47	**<0.05**	44.11	19.80	65.03	42.65	26.18	63.33	44.06	21.53	64.73	**<0.05**	**<0.05**	>0.05	**<0.05**
Dietary Fiber (g)	19.73	1.02	89.18	21.35	3.30	111.50	**<0.05**	16.53	3.82	56.88	19.48	4.40	111.50	26.82	6.67	143.72	**<0.05**	>0.05	**<0.05**	**<0.05**
Cholesterol (g)	265.88	18.58	1527.17	284.51	33.60	1331.00	**<0.05**	244.20	18.58	1210.69	264.39	49.90	1150.20	226.64	29.92	1106.98	**<0.05**	**<0.05**	>0.05	**<0.05**
PUFA (g)	11.84	0.54	64.63	14.09	1.60	75.70	**<0.05**	11.86	0.81	64.63	12.79	2.70	53.60	12.06	1.63	108.32	**<0.05**	**<0.05**	>0.05	>0.05
SFA (g)	26.00	3.56	111.78	29.93	5.90	119.60	**<0.05**	26.58	4.88	111.78	29.38	5.90	87.60	21.39	4.13	151.31	**<0.05**	**<0.05**	**<0.05**	**<0.05**
MUFA (g)	22.02	0.98	108.45	26.91	4.20	99.10	**<0.05**	22.64	1.73	98.65	27.33	6.90	89.60	25.90	4.35	207.53	**<0.05**	**<0.05**	**<0.05**	>0.05
Na (mg)	1617.74	173.60	21308.18	1698.76	151.20	8377.70	**<0.05**	1384.28	226.81	5279.00	1535.42	151.20	4254.20	1226.52	161.45	4045.03	**<0.05**	**<0.05**	>0.05	**<0.05**

PUFA: Polyunsaturated fatty acids, SFA:saturated fatty acids, MUFA:Monounsaturated fatty acids Note: p^1 = comparison between CeviCal and BeBIS; p^2 = comparison between TürKomp and CeviCal; p^3 = comparison between TürKomp and BeBIS. Decimal points are standardized using dots

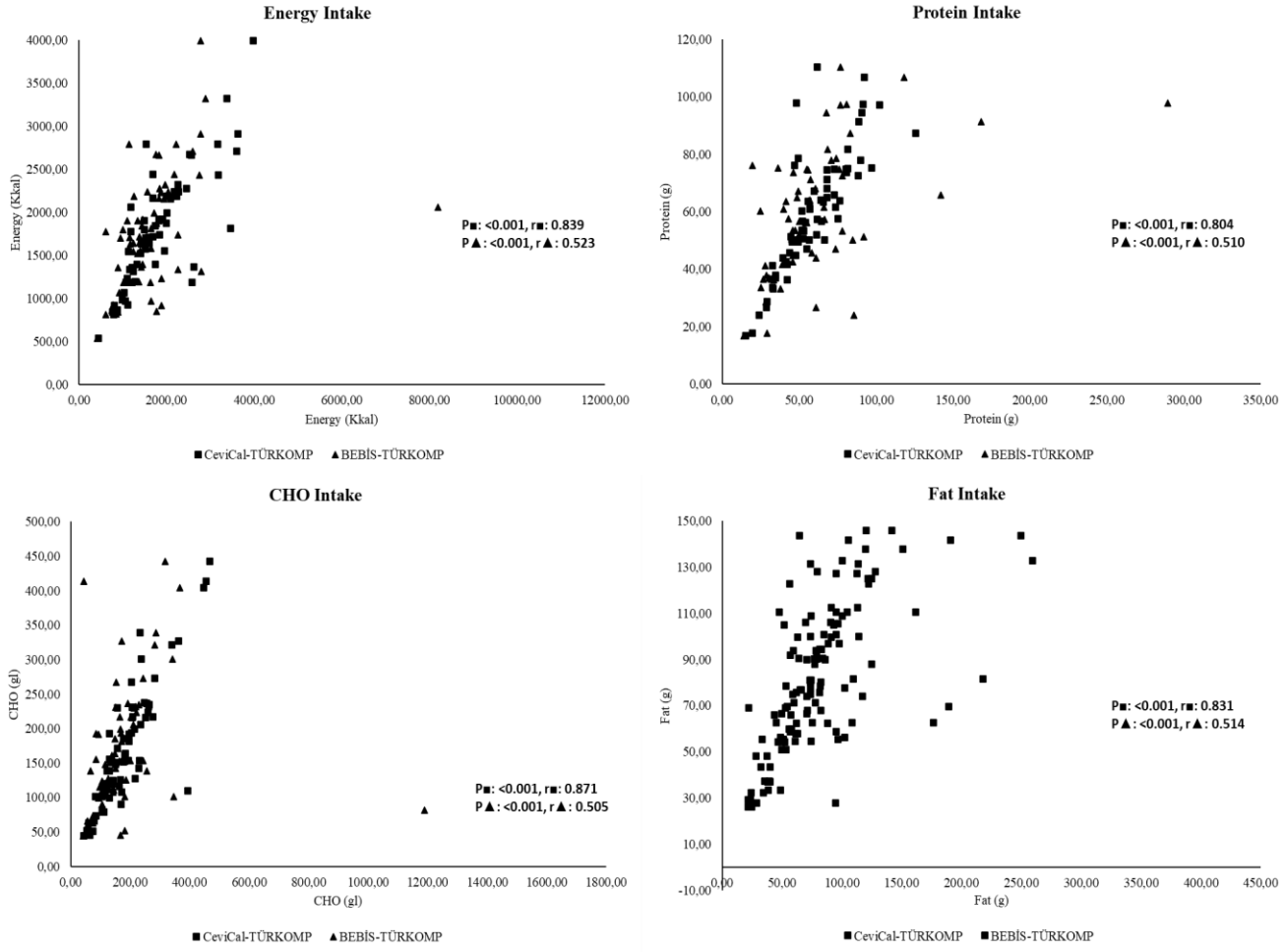

Figure 2. Correlation of nutrient consumption frequencies with energy, protein, carbohydrate, and fat values

The main reason for these differences lies in the content and scope of the databases on which the software is based. BeBIS uses a comprehensive European database that includes many processed and fortified foods. This can lead to higher reported values, especially for micronutrients.

CeviCal, on the other hand, works with a localized database that is more compatible with TürKomp, providing more consistent and nationally appropriate results, particularly for macronutrients. In addition, the user interfaces and data entry systems of the software may also contribute to differences in results:

CeviCal is a newer, web-based platform that enables integrated tracking of nutritional data and information, such as physical activity and medication use. It offers real-time data tracking and personalized feedback features. However, the scope of its database is more limited than that of BeBIS.

BeBIS, in contrast, has a more established and detailed database but lacks personalized and dynamic analysis tools.

Some studies in the literature also support these differences. For example, in studies evaluating the menus of preschool children using BeBIS, the menus were insufficient in meeting nutritional requirements (Yilmaz Akyüz & Sezgin, 2020). In studies conducted with university students, deviations from reference values in energy and fat intake were reported (Garipağaoğlu et al., 2012; Geçim & Terzi, 2023). In another study conducted with university students, the nutrient intake was reported to be in line with reference values (Çakır et al., 2018). In contrast, in a similar study involving medical students who had received nutrition education, fat intake exceeded the TÜBER reference values while energy intake remained below the recommended levels (Garipağaoğlu et al., 2012).

TürKomp posed certain limitations in this study due to including only raw foods and lacking a direct data entry system. These limitations were addressed using a customized Excel format in which cooking losses were calculated using TÜBER data, and recipes were formulated and included. However, this also indicates

that TürKomp needs a more integrated and analysis-oriented system. TürKomp was developed by TÜBİTAK using advanced laboratory analysis techniques and complies with international standards (TürKomp, 2015). In a previous study, individuals' vitamin C intake was estimated using the TürKomp database, while plasma ascorbic acid concentrations were determined through High-Performance Liquid Chromatography (HPLC), and a positive correlation was found (Emiroğlu et al., 2020). However, another study comparing in vitro B vitamin content of various bread types found that TürKomp values were significantly lower (Yaman, 2019).

CeviCal showed better alignment with TürKomp in terms of macronutrients and stood out with its user-friendly interface and suitability for clinical use.

Although BeBIS may provide greater accuracy for some micronutrients due to its more comprehensive database, it also carries a risk of deviating from the local context.

These findings suggest that, technical capabilities, study context and database compatibility should address when selecting nutrient analysis software.

Regression models were not applied as this study aimed primarily at comparing agreement between software outputs rather than predicting nutrient outcomes. Further studies may consider multivariate regression analyses. Further studies should include validating these software programs with biochemical markers, testing with broader and more diverse samples, and assessing user experience.

5. Conclusions

No significant differences were observed between CeviCal and TürKomp in terms of macronutrients, such as carbohydrates, proteins, and fats. Similarly, no inconsistencies between BeBIS and TürKomp concerning fatty acids and selected micronutrients were noted. Standardizing portion sizes and conducting analyses based on 100 grams of food yielded highly consistent results in CeviCal. The correlation between CeviCal and TürKomp was stronger than with the other software programs.

Accurate food composition data are critically important for enhancing nutrition awareness and protect public health. Food composition database programs can serve as practical tools for this purpose; however, inconsistencies existing data raise concerns about their reliability. This study showed that the widely used BeBIS and CeviCal programs in Türkiye exhibit some differences when compared with TürKomp data.

As the scope of research expands, it will be possible to address the shortcomings of these programs, leading to more reliable outcomes in public health. Comprehensive studies comparing data from different nutrient analysis software should also be conducted.

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Previous Presentation

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Declaration of Competing Interest

The authors declare that they have no financial or non-financial competing interests.

Author's Contributions

F. Cesur (0000-0003-2062-098X): *Conceptualization, Methodology, Data Curation, Formal Analysis, Writing – Original Draft, Writing – Review & Editing, Final Approval.*
S. Küçükyıldız (0009-0001-0220-7051): *Writing – Review & Editing, Final Approval*
B. Uygur (0009-0004-4966-813X): *Writing – Review & Editing, Final Approval.*
B.N. Kafadar (0009-0005-1971-2950): *Writing – Review & Editing, Final Approval.*

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A Comprehensive Review on Shalgam (Şalgam), a Traditional Turkish Beverage

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Abstract

Shalgam (şalgam) beverage is a traditional Turkish drink produced through the lactic acid fermentation of root vegetables, such as black carrots and turnips. The drink is especially popular in southern regions of Türkiye and is now widely consumed across the country. In recent years, Shalgam beverage has gained popularity beyond its traditional cultural context and now holds growing commercial potential internationally. This review provides a comprehensive overview of the traditional production methods of Shalgam beverage, including both conventional and direct fermentation techniques, and presents a detailed example of a representative production process. The chemical composition and nutritional attributes of the beverage are also examined. Due to its content of anthocyanins, phenolic compounds, and lactic acid bacteria with potential probiotic properties, Shalgam beverage might have functional benefits. However, concerns regarding alcohol content, shelf life, use of preservatives, and a lack of standardization are also discussed. Traditional knowledge should be integrated with modern food technologies, and innovative approaches—such as controlled fermentation, starter cultures, and non-thermal preservation methods—should be promoted to improve product safety and quality. This review can be classified as an experience-based narrative review, combining practical knowledge with scientific literature to evaluate the benefits of traditional Shalgam beverage.

Keywords: Shalgam beverage, Şalgam, Traditional beverage, Lactic acid fermentation.

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1. Introduction

Traditional foods reflect a society's historical heritage, cultural memory, and life practices shaped by geographical conditions. These foods have been conserved for generations and have been enriched by knowledge, experience, and production techniques. Owing to its diverse geography and cultural richness, Türkiye hosts a variety of traditional foods, including beverages unique to different regions, such as ayran, boza, kefir, hoşaf, compote, salep, Turkish coffee, Turkish tea, lemonade, hardaliye, kımız, gilaburu juice, unripe grape juice (koruk suyu), şıra, sherbet, pickle juice, and Shalgam beverage. These beverages are not only appreciated for their taste, but also valued as cultural assets due to their historical background, production techniques, functional properties, and social significance. Produced in various ways throughout the country, these foods are unique to local raw materials, climate conditions, and traditional knowledge (Başlar, 2023).

Shalgam beverage is a traditional Turkish drink that is widely consumed across Türkiye, particularly in the southern provinces. The drink is produced by lactic acid fermentation of root vegetables, such as black carrots and turnips. With its distinct color, sour flavor, and refreshing nature, Shalgam beverage is commonly consumed alongside kebab dishes. Further to being a fermented beverage, Shalgam beverage is also described as a functional drink due to its high antioxidant potential and the presence of carotenoids, chlorogenic acids, anthocyanins, phenolic compounds, and lactic acid bacteria that have potential probiotic properties (Tanrıseven et al., 2018; Kafkaskıray, 2020).

According to the Turkish Standards Institute (TSE), Shalgam beverage is defined as: "a product obtained by fermenting a mixture of bulgur flour, sourdough, potable water, and edible salt through lactic acid fermentation, then blending the resulting extract with turnips (*Brassica rapa*), black carrots (*Daucus carota*), and optionally hot pepper powder, and subjecting the mixture to a second lactic acid fermentation; if desired, the product can be made shelf-

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stable by thermal processing" (TSE, 2003). Although the standard allows for thermal treatment to extend shelf life, it is not common in traditional production due to the sensory changes the process could cause (İrkilmez, 2017).

This review was prepared by combining the author's longstanding practical experience of Shalgam beverage production with the academic knowledge gained during graduate studies and research projects. Informed by relevant literature, this review critically examines practical knowledge within a scientific framework, and therefore qualifies as an experience-based narrative review.

2. Production of Shalgam Beverage

Shalgam beverage is a fermented drink that can be produced in various ways depending on regional traditions. In addition to variations in traditional methods, the industrialization of Shalgam beverage production has also led to significant changes in production processes. With advancing technologies, such variations are expected to continue evolving. At present, two main production methods are widely recognized: the traditional method and the direct method. To understand these methods, it is essential to first examine the ingredients used in this unique fermentation process, as the selection and preparation of raw materials play a crucial role in the quality and safety of the final product.

2.1. Ingredients

The production of Shalgam beverage involves various raw materials that contribute to its unique flavor, aroma, color, and microbiological quality. The main ingredients include black carrot, turnip, bulgur flour, rock salt, and yeast (*Saccharomyces cerevisiae*). These components are essential not only in traditional production, but also in industrial applications.

Black carrot (*Daucus carota L.*): Black carrot is the primary source of Shalgam beverage's characteristic dark red color and distinct aroma. During fermentation, anthocyanins released into the liquid contribute not only to coloration, but also enhance antioxidant capacity. Naturally occurring soluble sugars in the carrot serve as carbon sources for lactic acid bacteria, supporting effective fermentation. Typically, 10–20% of black carrot is used in production (Erten et al., 2008). Sliced or chopped black carrots can be used. Black carrot peels are generally retained or partially peeled; washing with warm water is acceptable while heat treatments, such as blanching should be avoided to preserve microbial activity and fermentation quality.

Bulgur flour (setik): Traditionally known as "setik", bulgur flour acts as a nutrient source for lactic acid bacteria and yeasts during fermentation. Bulgur flour is added at around 3% and plays a considerable role in initiating and sustaining fermentation and might also influence aroma development and the consistency of the beverage (Erten et al., 2008).

Yeast (sourdough or baker's yeast): In Shalgam beverage production, either sourdough or baker's yeast (*Saccharomyces cerevisiae)* is used as a microbial inoculum. Sourdough contains various lactic acid bacteria (eg, *L. plantarum*, *L. brevis*, and *L. fermentum*) and different yeast strains (Tangüler, 2010). Although these microorganisms can originate naturally from the ingredients when using traditional production methods, industrial production often uses starter cultures to enable controlled fermentation.

Rock salt: Salt not only contributes to taste, but also plays a crucial role in controlling the fermentation microbiota and inhibiting undesirable microorganism growth. Typically used at around 1%, rock salt is crucial for ensuring the safety and stability of the fermentation environment (Erten et al., 2008).

Turnip (*Brassica rapa L.*): Although the beverage is named after this root vegetable, its use in production is relatively limited. In some regional recipes, turnip is excluded while in others, it is be added in small amounts (eg, ~1%). Turnip contributes to flavor and aroma because it contains soluble sugars (eg, glucose, fructose, and sucrose) and minerals (Tangüler & Erten, 2009). Although its name comes from the turnip (meaning "şalgam" in Turkish) vegetable, the sensory and fermentation characteristics of the beverage are largely influenced by black carrots (Çakır, 2023).

Water: As in all fermentation processes, potable-quality water is essential in shalgam beverage production. Water ensures the extraction of soluble substances, supports microbial activity, and provides a homogeneous fermentation environment. Environmental factors, such as temperature (20–30°C), salt concentration, oxygen levels, and sunlight exposure significantly influence both microbial composition and the quality of the final product throughout the fermentation process (Erten et al., 2008; Çakır, 2023).

2.2. Traditional production method

The traditional production of Shalgam beverage consists of two main stages: dough fermentation and carrot fermentation (Figure 1).

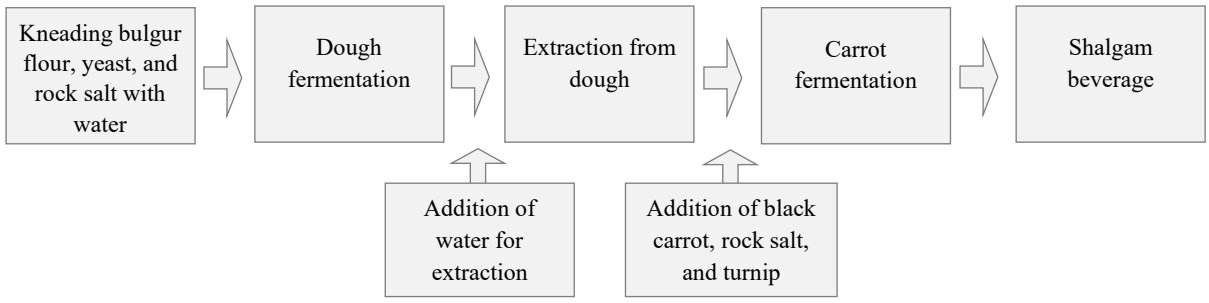

Figure 1. General production process of traditional Shalgam beverage (adapted from Erten et al., 2008)

2.2.1. First stage: Dough fermentation

The first stage, known as dough fermentation, begins with the mixing of bulgur flour, rock salt, and yeast. These ingredients are kneaded with water and left to ferment at room temperature for approximately 3–5 days. During this process, starch, proteins, vitamins, organic acid, and aroma compounds are released, supporting microbial growth. The activity of lactic acid bacteria and yeasts considerably increases the acidity of the dough and reduces the pH. Following dough fermentation, the extraction from dough process is performed where the fermented mass is subjected to sequential additions of water—typically three to five times—to obtain a liquid rich in microorganisms and soluble nutrients (Erten et al., 2008; Tangüler, 2010).

2.2.2. Second stage: Carrot fermentation

The second stage, known as carrot fermentation, begins with the use of the extraction liquid obtained from the dough fermentation stage. This extract, enriched with sourdough microbiota, provides a favorable microbial environment that initiates and supports carrot fermentation. Black carrots are added to the extracted liquid, along with rock salt and, optionally turnips. Fermentation is performed at ambient temperatures (25–30 °C) and in dark environments or in containers shielded from light (eg, wooden, plastic, or stainless steel tanks). Depending on fermentation conditions and temperature, this stage can take 1–3 weeks. The progress of fermentation can be monitored via the increase in acidity and the process is considered complete once the acidity levels stabilize. Upon completion of fermentation, separating the Shalgam beverage from the solids and storing it at refrigeration temperature is considered optimal for shelf life. Some producers choose to leave the fermented black carrots in the beverage to emphasize its traditional and natural characteristics (Erten et al., 2008; Tangüler, 2010).

2.2.3. Detailed example of a traditional production formulation

A detailed method and formulation based on the traditional approach for the production of 10 L of shalgam beverage is presented (Figure 2):

1-Preparation of ingredients: All raw materials required for production are procured. Among these, sourdough is of particular importance. If sourdough is not available, it should be prepared one day in advance. For 10 L of Shalgam beverage, 100 g of sourdough is used. To produce this amount, 61.6 g of flour, 1.2 g of salt, 3.2 g of fresh baker's yeast, and 34 g of water are mixed and kept at 25°C for 1 day.

2-Dough fermentation: The first fermentation stage begins by mixing 300 g of bulgur flour (48.4%), 20 g of rock salt (3.2%), 100 g of sourdough (16.1%), and approximately 200 mL of water (32.3%) until a semi-liquid dough is formed. This mixture is then left to ferment at 25°C for 3 days.

3-Extraction: After fermentation, the dough is subjected to four successive water extractions to recover both the microbial load (ie, yeasts and lactic acid bacteria) and water-soluble components (ie, starches, proteins, vitamins, minerals, aroma compounds, organic acids, etc.). The resulting liquid from this extraction is transferred to a separate container for further fermentation (eg, carrot fermentation or main fermentation).

4-Carrot fermentation: 1500 g of black carrot (15%), 117 g of rock salt (1.2%), and 100 g of turnip (1%) are added to the liquid obtained from the first fermentation. Water is added to reach a total volume of 10 L and the mixture is then allowed to ferment in a dark environment at 25°C. The progression of fermentation is monitored by titratable acidity, and fermentation is continued until the increase in acidity plateaus, typically lasting between 15 and 21 days.

5-Packaging: Once fermentation is complete, the Shalgam beverage is cooled to 4°C, filtered, and bottled for storage or consumption.

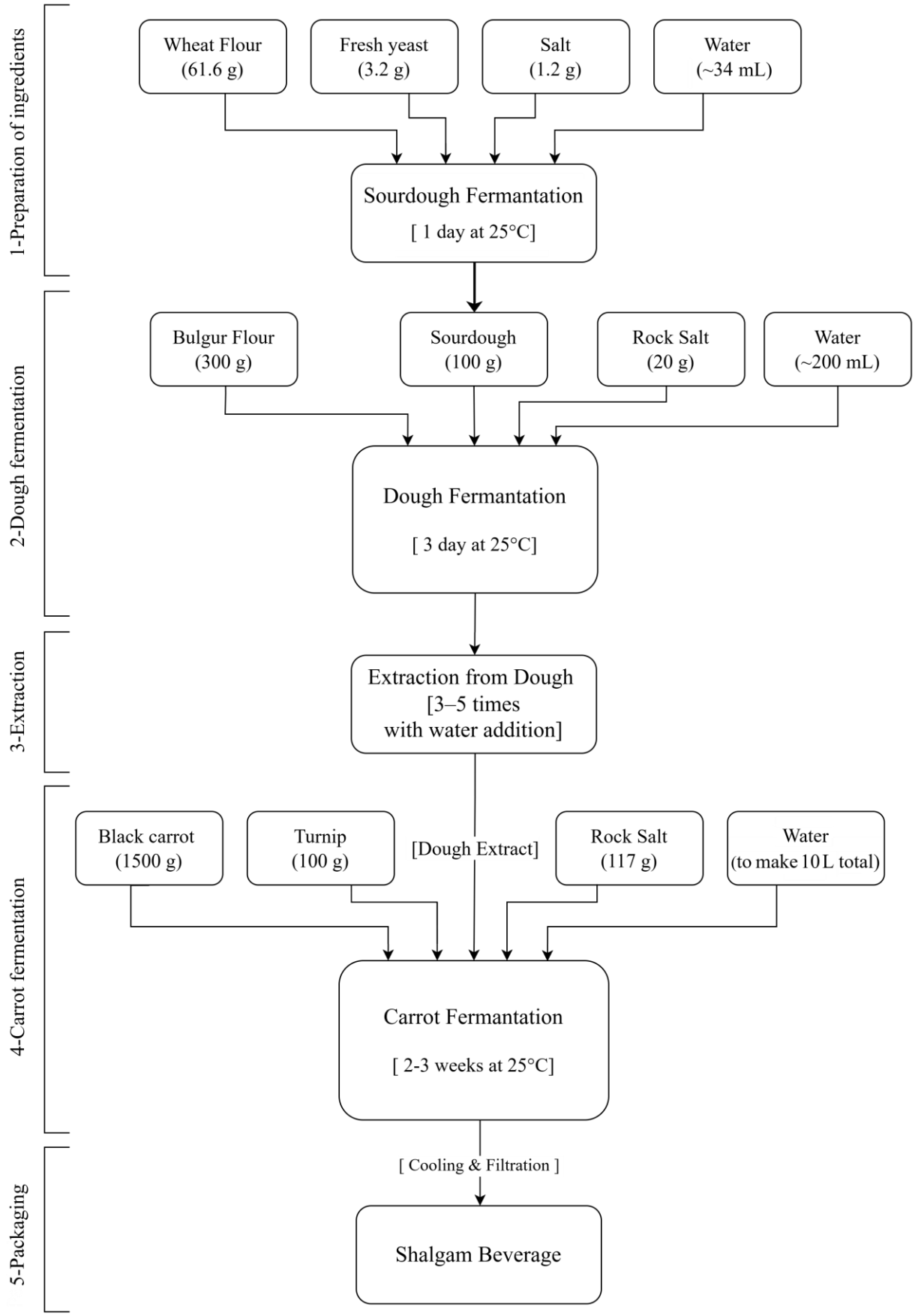

Figure 2. Detailed production process of traditional Shalgam beverage (developed by the author based on practical experience)

2.3. Direct production method

Direct fermentation is a more practical production method that omits the first stage (dough fermentation) used in the traditional process of Shalgam beverage production. With this method, all ingredients are added simultaneously into the fermentation vessel without a separate pre-fermentation step. In practice, chopped black carrots, bulgur flour, salt, turnip, water, and a microbial starter—either baker's yeast (Saccharomyces cerevisiae) or sourdough—are combined directly in the fermentation tank. After thorough mixing, the mixture is left to ferment at room temperature (typically between 20–30°C) for an appropriate duration (Öztürk, 2009). During this period, anthocyanins released from the black carrot color of the beverage, while lactic acid bacteria and yeasts contribute to the development of the desired acidic taste and aroma. A schematic representation of the direct fermentation process is provided in Figure 3. The primary advantage of this method is its ability to shorten the production time and reduce processing steps. However, since the process lacks a dough fermentation phase, there is a greater dependency on the microbial starter and environmental conditions, which can lead to variations in product quality. The microbial load introduced at the beginning of the process might be lower compared with the traditional method, necessitating stricter control during fermentation (Erten et al., 2008).

2.4. Storage and shelf life

After production, Shalgam beverage should be stored under refrigeration to slow down the microbial activity and extend its shelf life. Subsequently, the drink is bottled using an appropriate method depending on the production scale. The most common methods used to extend shelf life are thermal processing and the addition of preservatives. Many small-scale producers of commercial Shalgam beverage continue to use natural or traditional methods, often without applying heat treatment or adding preservatives, instead primarily focusing on cold storage. In contrast, large-scale manufacturers—those distributing nationwide or exporting internationally—tend to use heat treatment, preservatives, or cold chain logistics to ensure extended shelf life and microbiological stability.

According to the Turkish Food Codex (2011), the maximum total amount of preservatives, such as E210 (benzoic acid), E211 (sodium benzoate), E212 (potassium benzoate), and E213 (calcium benzoate), allowed in Shalgam beverage is 200 mg/L. However, some producers report that even this amount is insufficient to prevent spoilage over time.

Due to its low effect on pH, pasteurization can extend the shelf life of Shalgam beverage by up to 1 year. However, while thermal treatment provides microbiological stability, it can negatively affect sensory attributes and damage the beverage's characteristic natural aroma. As alternatives, non-thermal preservation methods have been investigated. İrkilmez (2017) reported that ultrasound treatment could be used, while Erol et al. (2024) proposed ultraviolet treatment as a promising method to enhance shelf life without compromising product quality.

According to a market analysis conducted by Öztürk (2009), the microbiological characteristics of commercial Shalgam beverages are presented in table 1. Due to the high microbial activity in Shalgam produced using traditional methods, the product typically has a shelf life of only 1–2 months and gradually loses its desirable sensory characteristics.

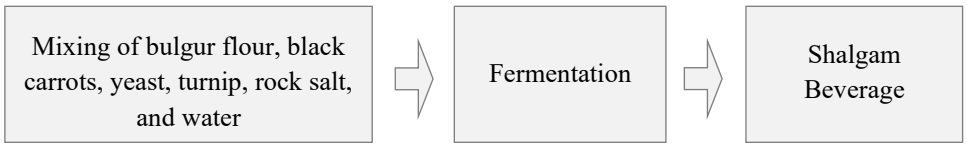

Figure 3. Direct production process of Shalgam beverage (adapted from Erten et al., 2008)

Table 1. Microbiological characteristics of commercial Shalgam beverages

Microbial group	*Min (log cfu/mL)*	*Max (log cfu/mL)*
Total mesophilic aerobic bacteria	3.26	7.66
Lactic acid bacteria	5.32	7.97
Total yeast count	5.72	8.15

Source: Öztürk (2009)

3. Composition of Shalgam Beverage

The approximate composition of Shalgam beverage, compiled from various sources, is presented in table 2. According to this data, Shalgam beverage is low-calorie because of low protein, fat, and carbohydrate content—providing approximately 2–4.6 kcal per 100 mL. The total dry matter content ranges between 20.7 and 31.9 g/L, with most of the weight for ash and salt (Öztürk, 2009). In particular, the salt content varies from 11.2 to 17.9 g/L, which is relatively high. The low pH value (pH 3.3–3.8) and high titratable acidity (66.40–99.10 meq/L) contribute to the beverage's characteristic sour taste (TSE, 2023; Deryaoğlu, 1990).

Since Shalgam beverage is a natural product of lactic acid fermentation, the formation of small amounts of ethanol is expected. These levels can vary depending on the fermentation duration, production conditions, and storage parameters. In Öztürk's (2009) study, the ethanol content ranged from 0.19 to 4.76 g/L, indicating that the alcohol level in Shalgam beverage can approach 5 g/L. To be classified as a non-alcoholic beverage, the ethanol content is required to be below 5 g/L in the USA (Code of Federal Regulations, 2024) and below 3 g/L in Türkiye (Turkish Food Codex, 2007). This classification is not only a legal requirement, but also a matter of cultural and religious significance. The presence of even small amounts of alcohol can be problematic for individuals from religious groups with strict dietary laws, such as Muslims and Jews. Beverages containing ethanol in higher percentages than these thresholds can conflict with halal and kosher dietary standards, which explicitly prohibit the consumption of alcoholic substances.

4. Health implications of Shalgam beverage

Shalgam beverage stands out as a healthy drink due to its sugar-free composition and fermented nature. Fermentation reduces sugar levels to nearly undetectable amounts, resulting in a low-calorie beverage with minimal glycemic impact. While Shalgam beverage contains high levels of lactic acid bacteria (especially *L. plantarum*) that have potential probiotic effects and is occasionally labeled as a probiotic drink, it does not fully meet the scientific criteria required for probiotic classification, such as strain identification, viability, and demonstrated health benefits in human (Kafkaskıray, 2020).

One of the most notable features of Shalgam beverage is its richness in bioactive compounds. Anthocyanins derived from black carrots not only impart the beverage's distinctive color, but also offer potent antioxidant properties. In addition, various phenolic compounds originating from vegetables are transferred into the liquid phase during fermentation, while newly formed phytochemicals contribute additional anti-inflammatory and potentially anticancer properties. With these characteristics, regular and moderate consumption of Shalgam beverage might support immune system health and contribute to the prevention of chronic diseases (Üçok & Tosun, 2012; Toktaş et al., 2018).

Shalgam beverage is exceptionally low in calories and sugars, making it suitable for individuals on calorie-restricted diets or those requiring low sugar intake. The fat and carbohydrate content is negligible. While Shalgam beverage is considered beneficial for health, certain potential risks should also be taken into

Table 2. Approximate composition of traditional Shalgam beverage

Component	*Min*	*Max*	*Reference*
Total solids (g/L)	20.7	31.9	Öztürk (2009)
Protein (g/L)	0.88	1.83	Deryaoğlu (1990)
Carbohydrate (g/L)	11.0	11.5	Label Review (2025)[a]
Sugar (g/L) [c]	0.15	6.48	Öztürk (2009)
Fiber (%)	0.02	0.67	Özler (1995)
Fat (g/L)	<LOD [b]	<LOD [b]	Label Review (2025)[a]
Ash (g/L)	12.9	20.7	Öztürk (2009)
Salt (g/L)	11.2	17.9	Öztürk (2009)
Energy (kcal/100 mL)	2	4.6	Label Review (2025)[a]
pH	3.3	3.8	TSE (2023)
Total acidity (meq/L)	66.40	99.10	Deryaoğlu (1990)
Ethanol (g/L)	0.19	4.76	Öztürk (2009)

[a] The data were obtained by examining the nutritional information declared on the product labels of three different traditional Shalgam beverage brands available on the Turkish market in 2025. [b] The component was reported as "0" by the manufacturer, possibly because it was below the limit of detection (LOD) of the analytical method used. [c] The total amount of sucrose, fructose, and glucose.

account. The amount of rock salt traditionally used during production might be relatively high (it can go up to 2%, according to TSE, 2003), which could be a limiting factor for individuals with salt sensitivity, such as those with hypertension. The drink's acidic nature is another factor that should be considered, particularly for individuals with gastric sensitivity (Surdea-Blaga et al., 2019). Additionally, the use of preservatives to extend shelf life requires careful evaluation. In non-pasteurized products, there is a risk of preservative levels exceeding legal limits, which raises both regulatory and health concerns.

Moreover, with traditional production, shelf life is often monitored visually, which can lead to the oversight of undesirable microbial activity, such as the growth of molds and yeasts. Mycotoxins produced by certain molds can pose major health risks to consumers. Therefore, hygienic production practices, controlled fermentation, cold storage (typically at refrigeration temperatures), and routine microbiological analyses are of crucial importance.

5. Industrial Potential of Shalgam Beverage

Shalgam beverage is primarily produced and consumed in the southern provinces of Türkiye, particularly in the Adana, Mersin, and Hatay regions. Since its introduction to the market in packaged form during the 1990s, Shalgam beverage popularity has gradually expanded throughout the country. By the 2000s, Shalgam beverage had become a widely consumed beverage across Türkiye (Üçok & Tosun, 2012). The drink's strong association with traditional kebab culture has secured its place both on restaurant menus and on shelves beside ready-to-drink products.

In line with developments in the food industry and evolving consumer demands, the production of Shalgam beverage has moved beyond traditional boundaries and into industrial-scale manufacturing. Many companies have begun integrating traditional production methods with modern food technology to develop pasteurized, preservative-free, organic, and even functional beverage versions. For industrial production, the use of starter cultures, controlled fermentation temperatures, and cold chain logistics are important techniques to ensure consistent product quality (Çakır, 2023).

In the Shalgam beverage sector, bottled shalgam products are of particular importance in terms of commercial potential. Doğanay stands out as the leading brand in the industry while brands, such as Kilikya, Fersan, and Kemal Kükrer, are also actively involved in production and distribution. Doğanay, which bases its production on thermal processing methods, reports on its official website (2025) that it exports to approximately 40 countries across America, Asia, Africa, and Europe (Doğanay Gıda, n.d.). Similarly, Kilikya states that it exports Shalgam beverage to more than 30 countries, including in Europe, America, Russia, and the Far East (Kilikya, n.d.). According to publicly available data, Doğanay's annual Shalgam beverage production capacity exceeds 500 million L (NTV, 2020), while Kilikya produces over 30 million L per year (Kilikya Shop, n.d.). Both companies play a key role in the globalization of this traditional Turkish fermented drink.

Shalgam beverage also holds significant potential in international markets. Export activities are already underway, particularly to European countries, such as Germany and France, where there are large Turkish communities, and also to Japan (Wikipedia, n.d.). The increasing global interest in fermented beverages with high antioxidant content indicates that Shalgam beverage could find a strong position within the functional beverage market. However, to realize this potential, packaging, labeling, and marketing strategies needs to be aligned with international standards. Nonetheless, several limiting factors are encountered in industrial production. According to the Turkish Food Codex (2007, 2011), there are legal restrictions on the levels of salt and preservatives that could be used in a Shalgam beverage. In an effort to extend shelf life, some producers can occasionally exceed these limits, making this a crucial area for food safety monitoring. Moreover, variations in production practices can lead to differences in taste, color, and turbidity among products, complicating quality standardization.

6. Conclusions and Recommendations

Shalgam beverage stands out as a low-calorie, traditionally produced fermented drink with high probiotic potential. Its rich content of antioxidants and functional compounds offers considerable opportunities for healthy nutrition. However, the drink also poses certain risks, such as high salt content, limited shelf life, and microbiological instability. Standardizing traditional production methods at an industrial scale and ensuring quality control are crucial steps to enhance the competitiveness of Shalgam beverage both in domestic and international markets.

Future research should focus on three key areas: reducing salt content while maintaining sensory properties, enhancing microbiological safety, and improving shelf life with innovative preservation

techniques. To achieve these goals, traditional production methods of Shalgam beverage should be standardized at the industrial level and supported by rigorous quality control systems. Controlled fermentation processes using starter cultures and the application of non-thermal preservation methods (eg, ultrasound or UV treatment) offer promising approaches for ensuring microbial stability. In this context, university–industry collaborations should be encouraged to advance research and development, particularly in starter culture innovation and preservation technologies that retain the beverage's traditional qualities.

Moreover, beyond scientific research and technological advancements, broader strategic initiatives are essential to unlock the full potential of Shalgam beverage in both local and international markets. Efforts should be made to better leverage its geographical indication status to preserve regional identity and distinguish it in competitive global settings. Enhancing industrial competitiveness with branding, marketing strategies, and international trade initiatives can support wider consumer recognition. These efforts, when supported by research and development outcomes, will further reinforce the cultural and economic value of the beverage.

Declaration of Competing Interest

The author declares that they have no financial or non-financial competing interests.

Author's Contributions

M.Ü. İrkilmez (0000-0003-1758-7840): *Conceptualization, Investigation, Methodology, Original Draft, and Editing.*

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