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Zerde (yellow rice pudding) prepared using different spices: Biological activity, physical properties, textural properties and aroma profile

Farklı baharatlar kullanılarak hazırlanan zerde (sarı renkli pirinçli puding): Biyolojik aktivite, fiziksel özellikler, tekstürel özellikler ve aroma profili

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Abstract

Zerde is a yellow rice-based milk dessert traditionally prepared with saffron. This study aimed to develop zerde formulations using alternative spices and to monitor the products during storage. Saffron, known as red gold, is the most expensive spice. In recent years, turmeric has attracted interest due to its positive health effects. Safflower, also referred to as false saffron, has been another product of interest. Five zerde formulations were created using saffron, safflower, turmeric, a turmeric-saffron combination, and a turmeric-safflower combination. The different spices and storage conditions significantly influenced the syneresis value, water-holding capacity, and b value (p<0.05). The highest antioxidant activity was found in the zerde formulation that included turmeric and safflower. The sample with safflower exhibited the highest syneresis value during storage. While ethyl acetate was abundant in the samples containing saffron and safflower, guaiacol was the prevalent aroma compound in turmeric formulations. The color values (Hunter L, a, and b) ranged from 69.47 to 72.91, (-)2.71 to (-5.76), and 22.31 to 25.74 during storage, respectively. The zerde formulated with turmeric received the highest scores for general acceptability and taste on the 4th day and 8th of storage. Turmeric or formulations containing turmeric could be used as a substitute for saffron, which is an expensive spice.

Keywords: Dairy desserts, flavor, texture, color, zerde

Öz

Zerde, geleneksel olarak safran kullanılarak hazırlanan sarı renkli pirinçli sütlü tatlıdır. Bu çalışmanın amacı, zerde üretiminde alternatif baharatlar kullanarak zerde formülasyonları geliştirmek ve bunları depolama süresince takip etmektir. Safran, dünyanın en pahalı baharatı olup "sarı altın" olarak bilinmektedir. Son yıllarda sağlık açısından olumlu etkileri nedeniyle zerdeçal önemli bir baharat haline gelmiştir. Aspir, yalancı safran olarak bilinmektedir. Bu çalışmada safran, aspir, zerdeçal, zerdeçal-safran kombinasyonu ve zerdeçal-aspir kombinasyonunu içeren beş farklı zerde formülasyonu hazırlanmıştır. Farklı baharatlar ve depolama süresi sineresis değerini, su tutma kapasitesini ve b değerini önemli ölçüde (p<0.05) etkilemiştir. Zerdeçal ve aspir içeren zerde formülasyonu en yüksek antioksidan aktiviteye sahiptir. Aspir kullanılan örnek, depolama sırasında en yüksek sineresis değerini sergilemiştir. Etil asetat safran ve aspir içeren örneklerde en fazla bulunurken, guaiacol zerdeçal içeren formülasyonlarda en fazla bulunan aroma bileşeni olmuştur. Renk değerleri (Hunter L, a ve b) sırasıyla 69.47-72.91, (-2.71) - (-5.76) ve 22.31-25.74 aralığında bulunmuştur. Zerdeçal ile formüle edilen zerde, depolamanın 4. ve 8. günlerinde en yüksek genel kabul edilebilirlik ve tat puanına sahip olmuştur. Pahalı bir baharat olan safranın yerine zerdeçal veya zerdeçal içeren formülasyonları kullanılabilir.

Anahtar kelimeler: Sütlü tatlılar, flavor, tekstür, renk, zerde

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1 Introduction

Zerde is a milk-based sweet made with rice, sugar, and saffron. Sholeh zard, shir-berenj, fereni, qaemaq, and boulame are very popular rice-based puddings in Iran. The zerde dessert is also known as Sholeh zard [1].

Saffron, which belongs to the Iridaceae family, is a spice obtained from the dried dark red stigmas of *Crocus sativus* L. [2]. It is the most expensive spice in the world. Saffron is also referred to as red gold. Due to its color, aroma, and intense taste, saffron is used as a food additive [3]. The most important components in saffron are crocin, picrocrocin, and safranal, which provide saffron's color, bitter taste, and odor. Iran is the leading country in saffron production worldwide [4]. Safflower (*Carthamus tinctorius L.*) is known by several names, such as false "Zaffer", "Fake Saffron " and "Dyer's Saffron". It is a bushy, herbaceous annual or winter annual plant with yellow, red, or orange flowers [5]. Safflower flowers contain two pigments: red (carthamin), which is insoluble in water, and yellow (carthamidin), which is soluble in water [6]. Safflower seeds contain oil (30%), protein (20%), and crude fiber (35%), and they are a good source of minerals (Zn, Cu, Mn, Fe), vitamins (thiamine, β-carotene), and tocopherol [7]. Turmeric (*Curcuma longa*) is a perennial herbaceous plant from the ginger family (Zingiberaceae), characterized by yellow flowers, large leaves, and rhizomes. It is frequently used in the cuisines of Malesia, India, China, Polynesia, and Thailand [8]. Curcumin, a yellow-orange pigment obtained from turmeric, offers various health benefits, such as anti-inflammatory, antioxidant, chemopreventive, antimicrobial, antiviral, and anticancer properties [9].

Zerde is a milk dessert that incorporates saffron in its preparation. However, zerde is lesser-known and produced in limited quantities due to the use of saffron, a costly spice. Therefore, exploring alternative spices to saffron is essential for broader adoption of zerde. There is no comprehensive study assessing the biological, physical, and aromatic effects of various spices in zerde production. This study aims to

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contribute to both scientific literature and the food industry. In this research, different formulations were created for zerde production utilizing safflower, turmeric, and saffron. This study aims to evaluate the impact of different spices on the biological activities, physical characteristics, textural properties, and aroma profile of zerde.

2 Materials and Methods

2.1 Materials

UHT milk, vanilla, corn starch, egg, sugar, and rice were procured from a local market in Denizli, Turkey. Safflower and turmeric powder were obtained from a herbalist in Denizli. Saffron was purchased from a herbalist in Safranbolu, Turkey.

2.2 Zerde Production

The base formulation for the zerde dessert includes milk (1 L), vanilla (7.5 g), sugar (210 g), corn starch (22.5 g), and egg yolk (25 g). Saffron and/or safflower should be soaked in water one day prior.

Approximately 10 kg of milk was used for each batch. The research was conducted in duplicate. The production was separated into five groups. The control sample was prepared with saffron (0.08 g/L). The second group (SF) was prepared using safflower (1 g/L). The third group (T) was made using turmeric (0.625 g/L milk). The fourth group (S-T) was prepared using saffron (0.04 g/L milk) and turmeric (0.312 g/L). The fifth group was prepared using turmeric (0.312 g/L milk) and safflower (0.5 g/L). First, rice was boiled in water until tender. After it was cooled, milk and spices were added. Saffron and safflower should be soaked in water overnight before production to transfer the color of the spices into the water; this colored water was then used in production. Powdered turmeric was used directly in the milk. Egg yolk and corn starch were mixed and dissolved in the milk at appropriate quantities at 40°C. After heating the mix to 80 °C, the egg yolk and corn starch solution were added. Then, sugar and sweet vanillin were mixed in appropriate quantities. This mixture was heated to 85 °C and continuously stirred until the desired consistency was achieved. The formulations were poured into containers and cooled down to 25 °C. Samples were stored in the refrigerator during the analyses. Each zerde formulation was prepared in duplicate. All analyses were performed at first day, 4th day, and 8th day.

2.3 Chemical composition and physical analyses

The total dry matter, protein, and fat content were determined according to the gravimetric procedure [10], the Kjeldahl Method [10], and the Gerber method, respectively [11]. The total sugar content was established using the Lane-Eynon method [12].

The color was analyzed using a Hunter colorimeter (Hunter Miniscan Xe, HunterLab, Reston, VA). The L (lightness), a (red-green), and b (yellow-blue) values were evaluated.

For water holding capacity (WHC), zerde samples (10 g) were placed in centrifuge tubes and centrifuged for 40 minutes at 5000 rpm using a Nüve NF 1200 R centrifuge (Ankara, Turkey). The supernatant was decanted, and the remaining part (R) was weighed. WHC (%) was calculated using the following equation:

R (g)*100 /initial sample (g). Syneresis was measured using the method outlined by Kadağan and Arslan [13].

2.4 Bioactive characteristics

The samples were extracted using the method described by Peker and Arslan [14]. Fifteen grams of the sample extract was mixed with 30 mL of methanol. The sample was homogenized for 1 minute, sonicated for 10 minutes, and kept in a shaker water bath for 15 minutes. Then, it was centrifuged (Nüve NF 1200 R, Ankara, Turkey) for 15 minutes at 4 °C and at 8500 rpm. The zerde samples were also analyzed for total phenolic content and antioxidant activity as described by Peker and Arslan [14]. Total phenolic content was measured using Folin–Ciocalteu (FC) reagent.

For this purpose, 5 mL of diluted FC reagent (1:10, FC: water) and 4 mL of sodium carbonate solution (75 g/L) were added to a 1 mL sample or standard. After the mixture was kept in the dark for 2 hours, absorbance and concentration were read in the wavelength spectrophotometer at 760 nm.

The antioxidant activity was determined using the 2.2-diphenyl-1-picrylhydrazyl radical (DPPH) scavenging method. Briefly, 2850 µL of the DPPH reagent was mixed with 150 µL of zerde samples in test tubes. The samples were left at room temperature in the dark for 60 minutes. Measurements were taken using a spectrophotometer at an absorbance of 515 nm.

2.5 Textural Analysis

The texture analysis was conducted following the methodology described by Kadağan and Arslan [14] utilizing a texture analyzer (Brookfield CT3, Brookfield Engineering Laboratory, Middleboro, MA, USA). The texture parameters of zerde samples were determined at ambient temperature using a texture profile analysis mode (TPA) with a cylinder probe (12.7 mm diameter) at a test speed of 2 mm/s.

2.6 Optical Microscopy

A light microscope (Olympus BX 50, Olympus Optical Co. Ltd., Japan) was utilized to examine the microstructure of milk dessert samples. After the samples were thinly spread on the slide, they were observed using 10x objectives. Photographs of the microstructure were captured using a Cameram 21 CMOS.

2.7 Determination of the aromatic profile

The aroma compounds in zerde samples were examined using solid phase microextraction with CAR/PDMS fibers (30/50 µm carboxen/polydimethylsiloxane, 1 cm long, Supelco, Bellefonte, CA, USA). A 3g sample was placed into a 20 mL headspace vial and maintained at 50 °C for 10 minutes. It was then extracted with CAR/PDMS fiber for 55 minutes and desorbed for 5 minutes before injected into the capillary column of the GC-MS device (Agilent 7000 Series Triple Quad). A capillary column (HP-5MS, 30 m length x 0.25 mm inner diameter x 0.25 µm film thickness, 5% phenyl methyl polysiloxane) was used to separate volatile compounds. The temperature of the GC oven was programmed to start at 35 °C for 5 minutes, increasing by 4 °C/min to 140 °C, where it was held for 5 minutes. The temperature was then raised to 250 °C at a rate of 10 °C per minute, maintaining it for 5 minutes. Helium served as the carrier gas, and the electron energy was set to 70 eV. Aroma compounds were identified using NIST14 and FLAVOR 2.

2.8 Sensory analysis

Sensory analysis was conducted with 30 participants (aged 20–50 years, consisting of 16 females and 14 males) from the graduate students, undergraduate students and members in the Food Engineering Department. After the samples were stored at 4 °C, they (20 mL cups, 4 °C) were labeled with three

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random digits and served. Participants scored the samples based on appearance, color, odor, taste, and general appreciation on a seven-point hedonic scale (1=dislike extremely, 4=neither like nor dislike, and 7=like extremely).

2.9 Statistical analyses

The experimental design evaluated the effects of five formulations, coded as S, SF, T, T-S, and T-SF, on the characteristics of zerde. A three-factor (time × formulation × batch) factorial experiment was conducted in this study. Each combination of factors (3 time × 5 formulation × 2 batch) included two replications for analysis. Statistical analysis was performed using the SPSS software (IBM Statistics Data Editor Version 20). The average values were compared using Duncan's test at the 5% ($p < 0.05$) significance level.

3 Results and Discussion

3.1 Chemical Analyses

The changes in dry matter, fat, protein contents, and pH values in all samples were not statistically significant ($p \geq 0.05$). The chemical analysis of the five formulations is presented shown in Table 1. The dry matter content of milk desserts called Muhallabi, which uses different spices (saffron and turmeric powder), was determined between 29.45% and 33.64% [15] The chemical composition of brown rice pudding reported by Puri et al. [16] was generally higher when compared to the current findings.

Table 1. Composition+standard deviation of zerde samples

Code	Dry matter (%)	Fat (%)	Protein (%)	Sugar (%)	pH
S	30.17±0.81	2.93±0.25	2.98±0.10	19.23±3.28	6.57±0.32
SF	30.37±1.03	2.93±0.32	3.00±0.06	18.37±3.58	6.55±0.02
T	30.23±1.25	3.10±0.17	2.99±0.09	18.88±2.55	6.54±0.02
T-S	30.79±1.29	2.73±0.12	2.85±0.1	16.85±3.43	6.51±0.06
T-SF	29.56±1.27	2.80±0.26	2.95±0.02	17.37±2.66	6.50±0.02

3.2 Physical Properties

The effects of different formulations and storage periods on syneresis, water-holding capacity, and b values were significant ($p<0.05$). Table 2 indicates that the highest serum separation and water-holding capacity among zerde samples were achieved with the SF and T-S samples. In starch-based systems, syneresis can occur during storage due to the reorganization and retrogradation of starch molecules [17]. In a study on turmeric powder and turmeric starch, the water-binding capacity of the starch derived from turmeric (up to 70°C) was lower than that of the dried and cured turmeric samples. Researchers suggested that this difference could be attributed to turmeric powder's protein and dietary fiber content. They reported that dried turmeric powder's protein content and dietary fiber level were 9.12-9.27% and 3.41-4.10%, respectively [18]. Similarly, in our study, the turmeric formulations demonstrated higher water-holding capacity and lower syneresis values than the other samples. The interactions between rice starch and milk proteins create the desired structure in such dairy desserts.

Product formulations and processes, such as heat treatment time, mixing, and cooling, affect the stability of puddings [19]. Therefore, turmeric powder in the present study may positively affect water binding due to its chemical composition. At the end of storage, the T code sample exhibited the lowest syneresis. The syneresis values of all samples increased compared to the initial values. The samples' highest and lowest L values were obtained for T and T-S, at 72.91 and 70.55, respectively, at the beginning of storage. Generally, the a values of zerde samples changed in the order of T> T-SF>SF> T-S > control during storage. Table 2 shows that among the zerde types, the T-S sample had the highest b value. Since the b values were positive in the zerde samples, yellowness was noted in the products. Comparatively, the T sample had the second highest b value, followed by S, T-SF, and SF. Majzoobi et al. [20] reported that the L, a, and b values of milk desserts enriched with wheat germ ranged from 65.0 to 83.33, -6 to -9, and 18 to 30, respectively. The a and b values were quite similar to those found in a study on pudding dessert by Okur [15]. Prasad et al. [21] reported lower L* and b values in herbal burfi (Indian dairy dessert) samples when compared to the present color findings.

The color values of the sweets were influenced by the presence of yellow and red pigments in the spices. While the most significant pigment responsible for the bright yellow-red hue of saffron is the crocin pigment [4], the substances that contribute to color formation in safflower spice are the "Carthamin" and "Carthamidin" pigments [6]. Turmeric contains curcumin, a naturally yellow-orange pigment [9].

3.3 Biological Activity

The influences of different treatments and storage periods on total phenolic content were not significant ($p \geq 0.05$). The effect of zerde types on antioxidant activity was significant ($p < 0.05$) (Table 3). Zerde with safflower and turmeric exhibited the highest antioxidant activity during storage. Okur [15] found that storage time and the use of turmeric and saffron in the Muhallebi milk dessert increased antioxidant activity. These results align with our study. In a study on milk desserts produced by adding ginger in varying proportions, formulation differences did not affect the total phenolic content [22]. Curcuminoids are the primary antioxidant compounds in turmeric. Additionally, turmeric contains compounds that influence different antioxidant capacities, such as γ-terpinene, ascorbic acid, beta-carotene, beta-sitosterol, caffeic acid, campesterol, and camphene [23]. Safflower contains a variety of phenolic compounds, including gallic acid, chlorogenic acid, syringic acid, quercetin-3-galactoside, and epicatechin [24]. Ivanova et al. [25] reported that the total phenolic content of dairy desserts with encapsulated cornelian cherry, chokeberry, and blackberry juices varied between 4.12 -14.53 mg GAE/100 g and 1.29-7.39 mg GAE/100 g on the 1st day and the 20th of storage, respectively. The antioxidant activity of high-protein, fat-free dairy reported by Kusio et al. [26] was higher when compared to the present results. In a low-calorie milk dessert study using ginger and cinnamon extract, it was found that desserts using 0.4% ginger had greater antioxidant properties than other samples [27].

3.4 Textural properties

The effect of different spices on textural parameters was not significant ($p \geq 0.05$). Regarding the textural properties (except hardness), a significant change ($p < 0.05$) was observed with the storage period. The textural properties of zerde samples mainly decreased with storage time (Table 4). This finding was consistent with the report by Kadağan and Arslan [13]. Cold storage promotes retrogradation in starch-based gels. Retrogradation influences the textural properties of the final product [28]. The functional properties of starch gel are affected by several factors, such as amylose content, the stiffness of the amylose matrix, the resilience of the remaining starch granules, and their interactions. Therefore, gel hardness could be associated with the amylose matrix and the filling effect of swollen starch granules [29]. In addition, heat treatment application and storage conditions can also affect the gel structure [30].

Table 2. Effect of different spices and storage periods on the physical properties of zerde

Properties	Storage period	S	SF	T	T- S	T-SF
Syneresis	1	18.21±2.69^{BCa}	19.48±1.74^{Ca}	13.39±1.44^{ABa}	14.94±5.12^{ABCab}	11.33±3.01^{Aa}
(%)	4	20.24±3.23^{Ba}	20.97±6.29^{Ba}	15.50±2.94^{ABab}	11.10±3.46^{Aa}	13.57±3.98^{Aab}
	8	24.06±4.63^{Aa}	24.12±3.54^{Aa}	18.85±3.39^{Ab}	20.33±3.94^{Ab}	20.11±6.48^{Ab}
Water	1	86.49±2.65^{Ab}	84.52±1.98^{Ab}	87.89±3.07^{Ab}	92.36±1.33^{Bb}	88.21±2.84^{Aa}
Holding	4	83.03±5.84^{ABab}	82.10±4.42^{Aab}	88.69±2.97^{BCb}	90.78±2.05^{Cb}	86.74±2.74^{ABCa}
capacity(%)	8	76.16±6.72^{Aa}	77.08±4.82^{Aa}	83.19±1.93^{Aa}	83.82±3.63^{Aa}	83.87±7.13^{Aa}
Hunter L	1	72.10±1.93^{AB}	71.65±1.86^{A}	72.91±0.83^{B}	70.55±0.44^{A}	71.96±0.41^{AB}
	4	72.42±1.81^{BC}	70.92±0.72^{AB}	72.71±0.61^{C}	69.47±0.91^{A}	71.29±0.84^{BC}
	8	71.63±0.36^{BC}	70.85±0.34^{AB}	72.60±0.76^{C}	70.21±1.36^{A}	71.51±0.51^{BC}
a	1	-2.71±0.53^{D}	-4.12±0.49^{BC}	-5.65±0.41^{A}	-3.93±0.76^{C}	-4.90±0.35^{AB}
	4	-2.91±0.36^{E}	-4.57±0.28^{C}	-5.76±0.19^{A}	-3.86±0.55^{D}	-5.05±0.15^{B}
	8	-2.88±0.18^{E}	-4.57±0.37^{C}	-5.76±0.25^{A}	-3.99±0.56^{D}	-5.08±0.03^{B}
b	1	25.14±0.48^{BCb}	23.00±0.71^{Aa}	25.14±1.26^{BCa}	25.74±0.46^{Cb}	24.34±0.97^{Ba}
	4	24.49±0.54^{Cab}	22.34±0.21^{Aa}	24.60±0.78^{Ca}	24.79±0.40^{Ca}	23.66±0.63^{Ba}
	8	24.28±0.48^{BCa}	22.31±0.29^{Aa}	24.73±0.72^{BCa}	24.94±0.29^{Ca}	23.99±0.69^{Ba}

Capital letters (A-E) denote a significant difference between zerde sweets for the same storage day at the $p<0.05$ level

Lowercase letters (a-b) denote a significant difference between the storage days for the same zerde sweets at the $p<0.05$ level

Table 3. Total phenolic content (mg GAE/100 g zerde) and antioxidant activity (µmol TE/100 g zerde) of different zerde formulations during storage.

Properties	Storage period	S	SF	T	T-S	T-SF
Total	1	21.60±5.47	25.51±4.75	24.96±2.40	24.00±3.64	27.86±1.44
phenolic	4	21.83±3.13	21.99±4.20	21.32±4.10	23.43±2.35	22.34±3.95
Content	8	25.24±2.89	25.64±1.87	22.03±2.88	20.98±1.45	22.67±3.30
Antioxidant	1	1.00±0.12^{A}	1.02±0.41^{A}	1.21±0.19^{A}	1.07±0.18^{A}	1.33±0.60^{A}
Activity	4	1.26±0.70^{A}	1.27±0.20^{A}	1.14±0.44^{A}	1.24±0.79^{A}	1.91±0.78^{A}
	8	1.19±0.20^{AB}	0.97±0.33^{A}	1.23±0.60^{AB}	1.80±0.96^{AB}	2.10±0.46^{B}

Capital letters (A-B) denote a significant difference between zerde sweets for the same storage day at the $p<0.05$ level)

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Table 4. Textural properties for five zerde samples during storage

Properties	Storage period	S	SF	T	T-S	T-SF
Hardness	1	19.42±3.96	18.83±4.26	20.33±9.66	18.66±5.60	24.16±4.51
(g)	4	18.41±2.85	18.58±5.41	17.83±5.37	22.08±3.99	21.50±2.42
	8	16.50±3.27	16.00±1.97	15.66±6.47	19.66±1.63	19.25±4.26
Springiness	1	14.32±1.08^{b}	12.76±1.35^{a}	12.26±2.27^{a}	11.63±2.13^{a}	13.54±3.41^{a}
(mm)	4	14.17±0.89^{b}	13.59±1.16^{a}	11.05±3.28^{a}	13.25±2.42^{a}	13.62±1.17^{a}
	8	11.51±1.18^{a}	12.30±1.62^{a}	11.36±2.48^{a}	11.73±1.90^{a}	11.15±2.57^{a}
Gumminess	1	11.31±2.96^{b}	11.80±2.33^{a}	11.58±5.77^{a}	10.17±3.40^{a}	13.03±3.87^{b}
(g)	4	10.08±1.02^{ab}	10.80±2.85^{a}	8.58±4.01^{a}	12.03±1.60^{a}	11.65±1.44^{ab}
	8	8.38±1.39^{a}	9.39±2.70^{a}	7.96±3.03^{a}	9.16±1.28^{a}	9.6±1.99^{a}
Cohesiveness	1	0.56±0.02^{b}	0.59±0.05^{a}	0.56±0.03^{a}	0.54±0.09^{a}	0.50±0.11^{a}
	4	0.55±0.03^{b}	0.58±0.07^{a}	0.48±0.06^{a}	0.50±0.06^{a}	0.54±0.06^{a}
	8	0.51±0.03^{a}	0.53±0.05^{a}	0.51±0.08^{a}	0.46±0.07^{a}	0.50±0.07^{a}
Chewiness	1	1.61±0.52^{b}	1.35±0.54^{a}	1.50±0.96^{a}	1.14±0.55^{a}	1.82±0.88^{a}
	4	1.40±0.12^{ab}	1.46±0.54^{a}	1.02±0.70^{a}	1.57±0.44^{a}	1.57±0.29^{a}
	8	1.01±0.21^{a}	1.05±0.32^{a}	0.93±0.47^{a}	1.07±0.32^{a}	1.13±0.31^{a}

Lowercase letters (a-b) denote a significant difference between the storage days for the same zerde sweets at the $p<0.05$ level.

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In the study on date pit puddings, it was stated that the hardness values were influenced by amylose content and the interactions of gelatinized starch fractions with the ingredients used in the pudding formulation. The hardness, cohesiveness, springiness, adhesiveness, and gumminess of date pits pudding were measured as 0. 28-0. 63 N, 0. 41-0. 69, 8. 63-9. 80 mm, 0. 73-1. 17 mJ, and 0. 16-0. 41, respectively [29]. Interactions between the milk content and remaining zerde components (mainly starch) can also affect the textural properties of the samples [20]. Majzoobi et al. [20] reported that the hardness value of milk desserts with added wheat germ varied between 47. 58 g and 77. 64 g, but the present findings were lower than these results. Chewiness indicates the amount of energy needed to chew food [31]. Chewiness values were lower than the results of Vidigal et al. [32]. A similar cohesiveness values were reported by Zarzycki et al. [33] in the dairy desserts with the addition oat gum concentration and carrageenan, who noted a range from 0. 491 to 0. 647. These hardness and gumminess results were lower than those reported by Ganje et al. [34]. On the other hand, other textural properties are quite similar to the results of the saffron milk dessert [34].

3.5 Microstructure

Microstructure affects the textural properties of food and is of great interest [35]. Figure 1 shows the micrographs of the product obtained for five different formulations.

In a study on a custard-like soy-based dessert with guava pulp, the addition of soy extract and dry ingredients affected the microstructure. Researchers found that incorporating dry ingredients supported the network structure and that a correlation existed between water binding capacity and microstructure [36]. Alimi et al. [37] studied the effect of native or hydrothermally modified banana starch on the microstructure properties of corn starch custard paste. The micrographs exhibited similar homogenous, non-continuous gel network structures for all custard paste samples.In the study conducted on instant puddings with low glycemic index, it was stated that the irregular shapes and proteins seen in the microstructure were related to the process conditions and the ingredients used [38]. In our study, no significant differences were observed between the microstructures of the samples. The analysis of samples' textural structures demonstrated that the spice addition did not lead to statistically significant differences, supporting our view.

3.6 Volatile compounds

Aromatic components are one of the parameters affecting consumer preferences [39]. The release of flavor in foods can be influenced by various factors such as the nature (texture, particle size, viscosity), the amount of flavoring agents, food matrix (lipid, protein, sugar, pectin, etc.), and oral physiology (saliva release, chewing, breathing, oral cavity volume, mouth) [40]. A total of 29 volatile compounds were identified in the zerde samples (Table 5). The sample included esters, terpenes, alcohols, ketones, aldehydes, phenolics, and others. The number of volatile compounds was 24, 21, 7, 19, and 7 in the S, SF, T, T-S, and T-SF zerde samples.

Ethyl esters are primarily responsible for sweet and fruity flavors [41]. Ethyl acetate was present in all samples. In another study conducted on milk samples subjected to various heat treatments, Hougaard et al. [42] noted that volatile compounds were affected by these heat treatments. The amount of ethyl acetate was higher in instant infusion pasteurized samples compared to raw milk, high-temperature short-time pasteurized milk, and milk pasteurized at 85 °C for 30 seconds. It has been suggested that ethyl acetate may be formed due to the heat catalysis of ethanol and acetic acid. Lubber and Butler [43] investigated the effects of texture and temperature on aroma release in model milk desserts. The researchers conducted a kinetic study by considering 4 aroma components, namely isoamyl acetate, octane-2-one, ethyl hexanoate, and allyl hexanoate. The ester content of the S-and SF samples exceeded 46%. Sample T contained only ethyl acetate from the ester group. Studies in model systems show that esters can interact with macromolecules found in custard compositions [43].

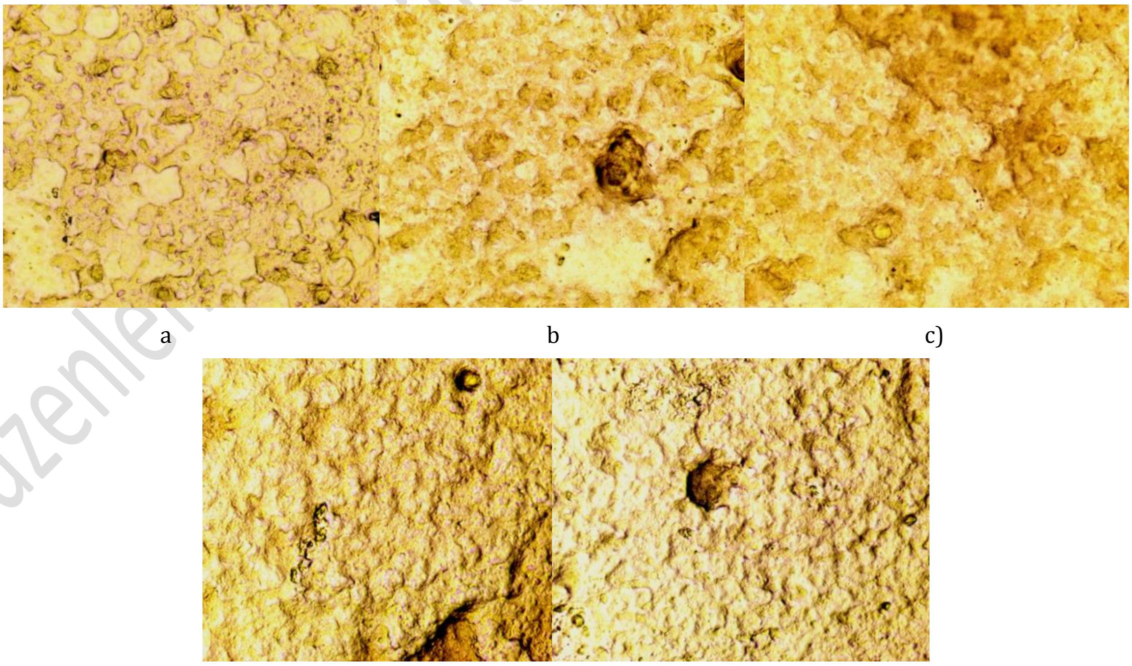
Ketones are present in both raw milk and processing parameters [44]. They are characterized by distinctive odors, including fruity, floral, mushroom, or musty notes, and have low perception thresholds [45]. Table 5 shows that the ketone group was not detected in samples T and T-SF, while the majority of ketone compounds were detected in SF.

Acetaldehyde has a light, fresh, green, and strong odor. It may be derived from various compounds, such as fatty acids, glucose, and amino acids [44]. Acetaldehyde was identified in all samples. Safranal is the major compound in the saffron aroma [46]. As expected, safranal was determined in the S and T-S samples.

The number and amount of alcohol and epoxy compounds in the samples were also quite low. Cyclobutanol concentrations in the S and SF samples were recorded as 5.34 % and 0.55%, respectively.

Certain volatile phenols were identified in the samples. In this study, guaiacol was the main aroma compound in the zerde samples containing turmeric. Guaiacol (a medicinal phenol) had the most pungent aroma, characterized by its bitterness, phenolic notes, and smoky quality. Kesen [39] identified 21 aroma compounds in turmeric. The researcher found that the 5 most abundant compounds in turmeric were determined as guaiacol, cuminic alcohol, isoamyl isobutyrate, α–curcumene and phenol, respectively. Guaiacol was determined all samples except SF sample. Vanillin was detected in the control sample, SF and T-S sample. Vanillin is one of the identified flavor components in saffron and safflower [47].

Terpenes are flavoring agents primarily found in plants. The terpenes found in milk originate from animal nutrition [42]. Additionally, terpenes can also be derived from plant materials added to dairy products [41, 48]. The highest concentration of a terpene compound was detected in the saffron sample. Terpene compounds were not identified in the T-SF sample. The most abundant terpene in the control sample was alpha-curcumene. The second most abundant terpene in the sample with saffron was limonene. Saffron is an excellent source of carotenoids and terpenes [49]. Turmeric rhizomes contain both mono- and sesquiterpenoid terpenoids [50]. The formulation and processing steps are believed to significantly impact the aroma compounds of zerde.



a b c)

d e)

Figure 1.Image of zerde samples produced with different spices under a light microscope with a 10X objective a: zerde prepared by adding saffron (S) b: zerde prepared by adding safflower(SF) c: zerde prepared by adding turmeric (T) d: zerde prepared by adding turmeric and saffron (T-S) e: zerde prepared by adding turmeric and safflower (T-SF)

Table 5. Volatile compounds of zerde samples

Compound (%)	S	SF	T	T-S	T-SF
Esters					
Ethyl acetate	44.33±3.14^{B}	39.15±3.96^{B}	1.87±0.42^{A}	0.93±0.21^{A}	0.53±0.14^{A}
Ethyl butyrate	1.47±0.10^{A}	1.53±0.11^{A}	n.d.	7.00±1.56^{B}	0.37±0.06^{A}
Ethyl hexanoate	0.39±0.06^{A}	0.22±0.03^{A}	n.d.	8.09±1.41^{B}	0.34±0.04^{A}
Hexyl formate	1.39±0.13	3.44±1.13	n.d.	1.19±0.73	n.d.
Butyl acetate	n.d.	1.66±0.15	n.d.	n.d.	n.d.
Vinyl acetate	n.d.	19.70±2.83	n.d.	n.d.	1,50±0.14
Ketones					
2-Pentanone	2.04±0.42^{B}	0.61±0.02^{A}	n.d.	0.36±0.04^{A}	n.d.
2-Heptanone	2.25±0.28^{A}	2.00±0.57^{A}	n.d.	3.65±0.42^{B}	n.d.
n-Octane	8.06±1.41^{B}	0.11±0.03^{A}	n.d.	n.d.	n.d.
2-Nonanone	0.79±0.14^{A}	23.90±3.96^{B}	n.d.	0.16±0.03^{A}	n.d.
2-undecanone	0.86±0.14^{A}	0.78±0.11^{A}	n.d.	2.44±0.28^{B}	n.d.
n-dodecane	1.07±0.17^{B}	0.21±0.03^{A}	n.d.	n.d.	n.d.
Aldehydes					
Acetaldehyde	1.65±0.28^{A}	0.63±0.14^{A}	0.44±0.14^{A}	27.62±4.80^{B}	1.75±0.21^{A}
Hexenal	0.57±0.14^{B}	0.14±0.03^{A}	n.d.	0.17±0.04^{A}	n.d.
Heptanal	0.62±0.14^{B}	0.16±0.03^{A}	n.d.	0.16±0.03^{A}	n.d.
Safranal	12.34±2.83^{B}	n.d	n.d.	1.07±0.28^{A}	n.d.
Alcohol					
Cyclobutanol	5.34±0.98^{B}	0.55±0.14^{A}	n.d.	n.d.	n.d.
Isoamyl alcohol	n.d.	1.18±0.14	n.d.	n.d........	1.29±0.28
Volatile Phenols					
Guaiacol	6.69±0.99	- n.d.	94.33±4.39	42.80±4.38	94.21±4.24
Vanillin	2.14±0.05	3.58±0.10	n.d.	0.20±0.02	n.d.
Terpene					
Limonene	0.89±0.07^{C}	0.16±0.03^{A}	0.24±0.04^{A}	0.64±0.10^{B}	n.d.
p-Cymene	0.50±0.05^{B}	n.d.	0.28±0.03^{A}	n.d.	n.d.
Calamenene	0.59±0.05	n.d.	n.d.	n.d.	n.d.
Alpha Curcumene	4.36±1.26^{B}	0.18±0.03^{A}	n.d.	0.23±0.04^{A}	n.d.
Farnesol (Z,E-)	0.82±0.06^{B}	n.d.	n.d.	0.30±0.04^{A}	n.d.
aR-Turmerone	0.66±0.07^{B}	0.10±0.01^{A}	n.d.	0.17±0.03^{A}	n.d.
4-carene	n.d.	n.d.	0.29±0.02	n.d.	n.d.
Other 2,3-Epoxybutane	0.66±0.04^{A}	n.d.	2.55±0.57^{B}	2.78±0.58^{B}	n.d.

Capital letters (A-B) denote a significant difference between zerde sweets at the $p<0.05$ level.

n.d.: not detected

Düzenlenmemiş Sürüm - Uncorrected Version

Martuscelli et al. [51] investigated the effect of fat content on seven aroma compounds (ethyl hexanoate, ethyl butanoate, benzyl acetate, ethyl 3-methyl butanoate, cis-3-hexenyl acetate, cis-3-hexenol, and hexanal) in strawberry-flavored milk desserts. In a study conducted on saffron-added cheese, 10 different aroma groups (aldehydes, ketones, alcohols, esters, sulfur compounds, terpenes, ethers, hydrocarbons, aromatic hydrocarbons, and others) were identified. In this study, it was determined that saffron-added and control cheeses had similar aroma profiles, except for the presence of safranal [52].

3.7 Sensory Properties

The findings indicated that the presence of different spices influenced the overall acceptability of the zerde samples; however, statistical analysis revealed no significant difference between the zerde types ($p \geq 0.05$). All sensory properties were significantly affected by the storage period (Table 6). Generally, the sensory properties of the samples were higher on the 4th day of storage compared to other days. There was a significant effect of various spices and storage time on the appearance and odor scores of zerde. The highest appearance score was recorded for the control on the 4th day. Compared to the other formulations, the zerde sample supplemented with turmeric powder exhibited the highest general acceptability on days 4 and 8 of the storage period. Conversely, the general acceptability scores of the samples were similar.

Choobkar et al. [53] found that as the amount of cinnamon powder increased, the appearance scores of puddings improved. In a study on puddings made with Iranian and Turkish saffron, it was found that as the quantity of saffron increased, both visual and oral consistency scores rose [54]. Kaur and Goswami [55] noted that the sensory scores of dairy desserts (Rasgulla) decreased with extended storage periods. Kumare et al. [56] reported that the overall acceptability of the milk dessert containing 0.8% black pepper powder and 1% turmeric powder was higher than that of other samples with black pepper-turmeric powder.

Düzenlenmemiş Sürüm - Uncorrected Version

Table 6.Sensory properties for five zerde samples during storage

Properties	Storage period	S	SF	T	T-S	T-SF
Appearance	1	4.79±1.08^{ABab}	4.76±1.12^{Abb}	4.67±0.87^{ABa}	4.33±1.28^{Aa}	4.98±0.92^{Ba}
	4	5.07±1.14^{Cb}	4.40±1.10^{Aab}	5.02±0.90^{Ca}	4.76±0.82^{Bb}	4.69±1.16^{Ba}
	8	4.26±0.91^{ABa}	4.17±1.06^{Ca}	4.57±0.94^{BCa}	4.52±1.07^{BCab}	4.90±1.14^{Ba}
Color	1	4.74±1.04^{a}	4.67±1.22^{a}	4.71±1.02^{a}	4.71±0.89^{a}	5.12±0.92^{a}
	4	5.33±1.24^{b}	5.02±0.96a	5.21±0.98b	5.12±0.80^{b}	5.12±1.13^{a}
	8	4.52±0.94^{a}	4.69±0.87^{a}	4.69±1.07^{a}	4.79±0.95^{a}	4.76±1.03^{a}
Odor	1	4.55±1.15^{ABa}	4.67±1.05^{Aba}	4.86±0.93^{Ba}	4.21±0.93^{Aa}	4.43±1.13^{Aba}
	4	5.10±1.06^{ABb}	5.02±1.22^{Aba}	4.98±1.32^{Aa}	5.10±1.01^{ABb}	5.19±0.99^{Bb}
	8	4.43±0.77^{ABa}	4.81±1.09^{Ba}	4.79±0.93^{Ba}	4.17±1.38^{Aa}	4.60±1.01^{Aba}
Taste	1	4.55±1.27^{ab}	4.43±1.17^{a}	4.48±1.13^{a}	4.90±1.1^{a}	4.69±1.16^{a}
	4	5.00±1.27^{b}	5.02±1.02^{b}	5.17±1.17^{b}	5.02±1.10^{a}	4.88±1.45^{a}
	8	4.33±1.05^{a}	4.69±1.16^{ab}	5.07±0.89^{b}	4.74±1.06^{a}	4.45±1.19^{a}
Consistency	1	4.93±1.22^{b}	4.10±1.27^{a}	4.29±1.04^{a}	4.88±0.97^{b}	4.76±1.17^{b}
	4	4.86±0.84^{b}	5.17±1.10^{b}	5.00±0.83^{b}	4.98±1.05^{b}	4.64±1.06b
	8	4.14±0.98^{a}	4.52±0.94^{a}	4.67±0.90^{a}	4.29±1.18^{a}	4.17±0.99^{a}
General	1	4.60±1.15^{ab}	4.43±1.09^{a}	4.38±0.91a	4.55±0.94^{ab}	4.76±1.14^{a}
acceptability	4	4.98±1.10^{b}	5.02±1.12^{b}	5.24±0.82b	4.88±0.89^{b}	4.64±1.27^{a}
	8	4.33±0.82^{a}	4.62±0.88^{ab}	4.98±0.75b	4.43±0.89^{a}	4.55±1.09^{a}

Capital letters (A-C) denote a significant difference between zerde sweets on the same storage day at the $p<0.05$ level.

Lowercase letters (a-b) denote a significant difference between the storage days for the same zerde sweets at the $p<0.05$ level.

4 Conclusions

The combination of turmeric and safflower increased antioxidant activity, positively affecting zerde desserts. The b value was significantly influenced by different spices and storage periods ($p<0.05$). All zerde samples exhibited a similar total phenolic content. While cohesiveness, gumminess, and chewiness progressively decreased over the storage period, the hardness value was not significantly affected by storage($p\geq0.05$). The most volatile compounds were detected in zerde samples containing saffron and safflower. Guaiacol was identified as a major volatile compound in zerde samples that included turmeric. Aroma compounds such as aldehydes, alcohols, ketones, volatile phenols, and terpenes were recorded in zerde samples. The effects of spices on Hunter L, a and b values were significant. The results revealed that the spices (saffron, safflower, turmeric) played distinct roles as ingredients in the zerde dessert. Zerde samples with added turmeric exhibited higher taste, consistency, and general acceptability compared to other samples during storage, with the exception of the first day. Turmeric or formulations containing turmeric may be utilized in zerde production.

5 Acknowledgement

6 Author contribution statement

Author 1 was responsible for developing the idea, designing the experiments, conducting the literature review, and writing the initial draft of the article; Author 2 contributed to the study design, evaluated the results, examined the findings, and wrote and reviewed the article.

7 Ethics committee approval and conflict of interest statement

Ethics committee approval was not required for the present study, and the authors declare no conflict of interest.

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Düzenlenmemis Sürüm - Uncorrected Version