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The effect of rice microgreen powder and microbial transglutaminase enzyme on the textural and sensorial characteristics of sponge cake during storage period

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ABSTRACT

Cakes are among the most widely consumed baked goods. Consumption of functional foods, including fortified cakes, can positively impact public health. In this study, the effect of adding rice microgreen powder (RMP) at four levels of 0, 2.5, 5 and 7.5% (replacement with flour, weight/weight) and microbial transglutaminase enzyme (TG) at two levels of 0, 0.15% on the textural characteristics and sensory properties of sponge cake was investigated. The results showed that adding RMP reduced the firmness, springiness, gumminess and chewiness and increased the cohesiveness of the fortified samples ($P<0.001$). Adding TG also significantly reduced the firmness and significantly increased ($P<0.01$) the cohesiveness, gumminess and chewiness of the cake samples. Storage time also increased the firmness, gumminess, and chewiness and decreased the cohesiveness and springiness of the samples ($P<0.001$). The adhesiveness of the samples was not affected by RMP and TG enzyme, but storage time increased it ($P<0.05$). Sensory evaluation of the samples also showed that although TG enzymatic treatment had no significant effect on these properties ($P>0.05$), the addition of RMP improved the color, aroma, and texture scores and significantly reduced ($P<0.001$) the taste score of the sponge cake samples. With the passage of time, all sensory properties also decreased ($P<0.001$). According to the acceptable texture quality and sensory properties (scores above 7, rated as good), the use of RMP at levels of 5-7.5% in combination with TG enzymatic treatment is recommended for sponge cake fortification.

1- Introduction

Cakes are one of the most popular baked goods due to their excellent texture and taste, and their consumption is of interest to all age groups. One of the important types of cakes is sponge cake, which by definition consists of at least 20% of its ingredients [1]. The main components of cake can be flour, oil, sugar and eggs, each of which has a functional and important role in the structural and qualitative characteristics of the product. Cake batter is a set of oil-in-water emulsion, foam (emulsion of air bubbles in the aqueous phase) and a complex colloidal system. In fact, cake batter is an oil-in-water (o/w) emulsion in which fat particles are irregularly placed in an aqueous phase containing dissolved sugar particles and eggs [2 and 3].

Today, the use of functional additives in the formulation of baked products such as sponge cake has attracted the attention of many researchers in order to achieve health benefits. However, in the production of these products, in addition to maintaining the texture, the product must have desirable sensory properties. Healthy food products provide our daily nutritional needs; while functional foods are rich in functional ingredients and are able to meet our usual nutritional needs beyond our usual requirements. In contrast to these products, currently, various types of foods with diverse and attractive sensory properties (aroma, taste, color, etc.) are produced and marketed to satisfy different tastes of people, which can endanger the health of consumers. The most important of these foods are fast food, the frequent consumption of which has created numerous problems for the health of the general public. Interestingly, in recent years, the consumption of both groups of foods has been increasing rapidly, and certainly, an individual's knowledge about the "role and importance of foods on human health" can be decisive in this regard [4]. Functional foods are part of the daily diet that, in addition to basic nutritional properties, have effects beyond nutritional value on the health of the community [5]. Today, microgreen products are known as rich sources of nutrients and are used in the preparation of various salads and fast foods. For this reason, microgreens are also called "functional foods" or "superfoods" [6]. Rice, with the scientific name *Oryza sativa*, is an annual plant from the Gramineae family, which is considered the most important crop in the world after wheat [7]. In terms of production, rice ranks second among cereal crops. Most of the world's population, especially in Southwest Asia, India, and China, depends on rice as a staple food [4]. Although the use of various additives with functional properties such as lactulose [8, 9], date kernel powder [10], and pomegranate kernel powder [11] has been proposed for the production of functional baked products, the use of microgreens, especially the use of rice microgreens in the production of various cakes, has received less attention.

Enzymes are widely used in the food industry because they perform diverse functions that facilitate processing and improve product quality. They are generally regarded as safe (GRAS) and typically lose activity during thermal processing such as baking. Enzymatic treatments offer a preferable alternative to chemical additives for achieving desired functional and sensory properties [12]. In particular, microbial enzymes—most notably microbial transglutaminase (MTGase)—have gained attention for their ability to catalyze covalent cross-linking of proteins, thereby modifying protein functionality and enabling the development of novel food textures and products [13-15]. Transglutaminase (TG) (protein glutamine γ-glutamyl transferase, EC 2.3.2.13) is known to catalyze the transfer reaction between an amide group in a protein-bound glutamine and an ε-amino group in a protein-bound lysine side chain, which results in the formation of cross-links between protein molecules. This transferase enzyme is widely used to modify the functional properties of proteins in various foods. It has been reported that enzymatic treatment with microbial TG improves the textural properties of the product by retaining water in the protein matrix of foods [16, 17].

Although various studies have been conducted on the use of the enzyme transglutaminase on bread and other baked goods, no study has been conducted to investigate the effect of this enzyme on sponge cake containing rice microgreen powder. Therefore, the present study aimed to investigate the effect of adding rice microgreen powder (RMP) and transglutaminase (TG) enzyme on the textural and sensory properties of functional sponge cake.

2- Materials and methods

2-1- Raw materials

Wheat flour for cakes with an extraction percentage of 73% (Setareh Komijan Flour Factory, Arak), vegetable oil (Behshahr Industrial Company, Iran), ground sugar, egg yolk, baking powder (Golvash Company, Isfahan) with ingredients such as sodium acid pyrophosphate, monocalcium phosphate monohydrate, sodium bicarbonate, wheat starch, vanilla with a heat resistance of above 280 degrees Celsius (Behtam Powder Company, Karaj) and microbial transglutaminase enzyme (TG) prepared from Streptoverticillium morbaeaense, with the trademark ACTIVA YG (Ajinomato Company, France) were used. The activity of each gram of this enzyme powder was determined to be 100 units per gram of protein. The TG enzyme powder used included lactose, yeast extract, maltodextrin, vegetable oil, and TG enzyme.

2-2- Methods for preparing rice microgreen powder and cake

2-2-1- Rice microgreen powder

To prepare rice microgreens, rice seedlings with a length of 5 ± 2.5 cm were thoroughly washed and after rinsing at 48 °C, dried in an oven for about 48 hours (until a constant weight was reached). After grinding, the resulting powder was passed through a 60 mesh sieve (250 µm) and the rice microgreen powder was used in the cake formulation at a rate of 2.5, 5 and 7.5% (w/w) to replace the flour used.

2-2-2- Cake production

Sponge cake samples containing rice microgreen powder were produced according to the method of Jahanbakhshi and Ansari [18] with slight modifications. First, powdered ingredients including: 100 g of wholemeal flour, 72 g of sugar, 1.34 g of baking powder, and 0.4 g of vanilla were mixed together. Then, 72 g of egg yolk and white mixture along with 57 g of liquid corn oil and 35 g of water were added to it and mixed well. Rice microgreen powder (RMP) was substituted for the flour in the cake formulation at 2.5, 5, and 7.5 percent (w/w). Also, microbial transglutaminase (TG) enzyme was added to the mixture at levels of 0 and 0.15 percent along with the rest of the powdered ingredients. The sample without rice microgreen powder and TG enzyme was considered as a control sample. The prepared dough (35 g samples) was transferred into a 3 cm diameter aluminum mold containing greased parchment paper and then the molds were placed in an oven at 200°C for 17 minutes. After baking, the cakes were removed from the oven and allowed to cool completely for 30 minutes. Then, the cake samples were packaged in polyethylene bags and stored at room temperature (23±2°C) until further tests.

2-3- Textural properties of cake

The texture profile of the cake samples was measured using a TA-XT-PLUS texture analyzer (Made in England, Micro stable system), according to the method of Saeidi et al. [19] with some modifications. The texture characteristics of the cake samples were determined after 1 and 7 days of production. Texture analysis included several different factors such as firmness, cohesiveness, adhesiveness, springiness, and gumminess. For this purpose, a cylindrical piece with dimensions of 2 × 2 cm (diameter × height) was first cut from the cake core (the lower 1 cm of the cake surface) using a mold, and the texture profile characteristics were determined using a cylindrical probe with a diameter of 36 mm with a compression rate of 50% (Figure 1). The test speed was set to 1 mm/s and the post-test speed was set to 5 mm/s. The threshold or sensitivity of the probe contact force with the sample was considered to be 3 g. Each test was performed at least 3 times and the average results were recorded.

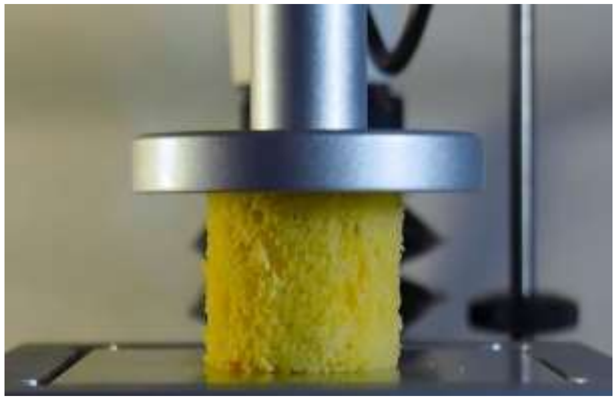

Figure 1. Texture profile analysis (TPA) of sponge cakes using TA-XT-PLUS device.

2-4- Sensory evaluation

The sensory properties of the cake were evaluated after 1 and 7 days of storage at 23±2°C in polyethylene bags by 20 evaluators (students and professors of the Department of Food Science and Technology, with an age range of 19-53 years). Scoring was based on a hedonic or preference test and a scale of 1-9 (1- unacceptable, 2- very bad, 3- bad, 4- slightly bad, 5- average, 6- good, 7- very good, 8- excellent and 9- very excellent). The sensory properties of the cake included color, odor, appearance, taste and texture [20].

2-5- Analysis of data

In this study, 8 cake treatments were produced with two variables: rice microgreen powder at four levels (0, 2.5, 5 and 7.5%) and transglutaminase enzymatic treatment at two levels (0 and 0.15%). Data were analyzed through factorial test in a completely randomized design using SPSS version 23 and the data means were compared using Duncan's test at the 5% level. All treatments were produced in 3 replicates and the textural properties and sensory characteristics of the cake samples were evaluated after production.

3- Results and discussion

3-1- Cake texture evaluation

Firmness is one of the important and influential factors in cake texture and this factor is very effective in consumer acceptance and satisfaction. Firmness is considered as the maximum force required in the first compression (biting, chewing and swallowing) of food products [21]. The results showed that transglutaminase (TG) enzymatic treatment and the addition of rice microgreen powder (RMP) significantly ($p<0.001$) reduced the firmness of cake samples (Table 1). In contrast, storage time significantly increased firmness ($p<0.001$). Similar to other studies conducted in the field of baked products [22 and 23], the results of this study indicated an inverse relationship between specific volume and cake firmness; so that cake samples with lower specific volume had higher firmness. As the RMP content increased from 0% to 7.5%, the stiffness value decreased from 420.65 to 300.25 g-force (Figure 2). The effect of RMP on cake texture can be explained by its lower solubility and water absorption capacity compared to wheat flour. RMP, like other dietary fibers, has a lower water absorption due to its higher lignin content compared to cereal bran, which increases the water content available for dissolving sugar in the medium [24]. Therefore, less sugar crystallizes during cake baking, affecting the texture of the final product [25]. Also, due to the lower water absorption capacity of RMP, more water is absorbed by wheat flour, thus improving the gluten protein network of the dough. In addition, in the final stages of baking, due to the low water absorption capacity of RMP, the unbound water of the cake evaporates more easily, leaving larger pores and increasing the number of pores. Therefore, the specific volume of the cake increases and its firmness decreases. The increase in firmness is related to the decrease in the number and size of air bubbles, since it increases the force required for compression [26]. As mentioned, the increase in the amount of gluten water absorption due to higher amounts of rice microgreen powder and fiber leads to an increase in the formation of gluten networks, which increases the air entrapment capacity of the cake [27, 28]. In support of the results of this study, a significant decrease in the firmness of sponge cake has been reported as a result of the addition of olive kernel powder [18] and pumpkin powder [29]. Lebesi and Tzia [24] stated that the use of fiber in sponge cake formulation and its effect on product quality depends on the soluble or insoluble fiber; So that using soluble fiber makes the cake softer, while using the insoluble type increases the firmness of the product.

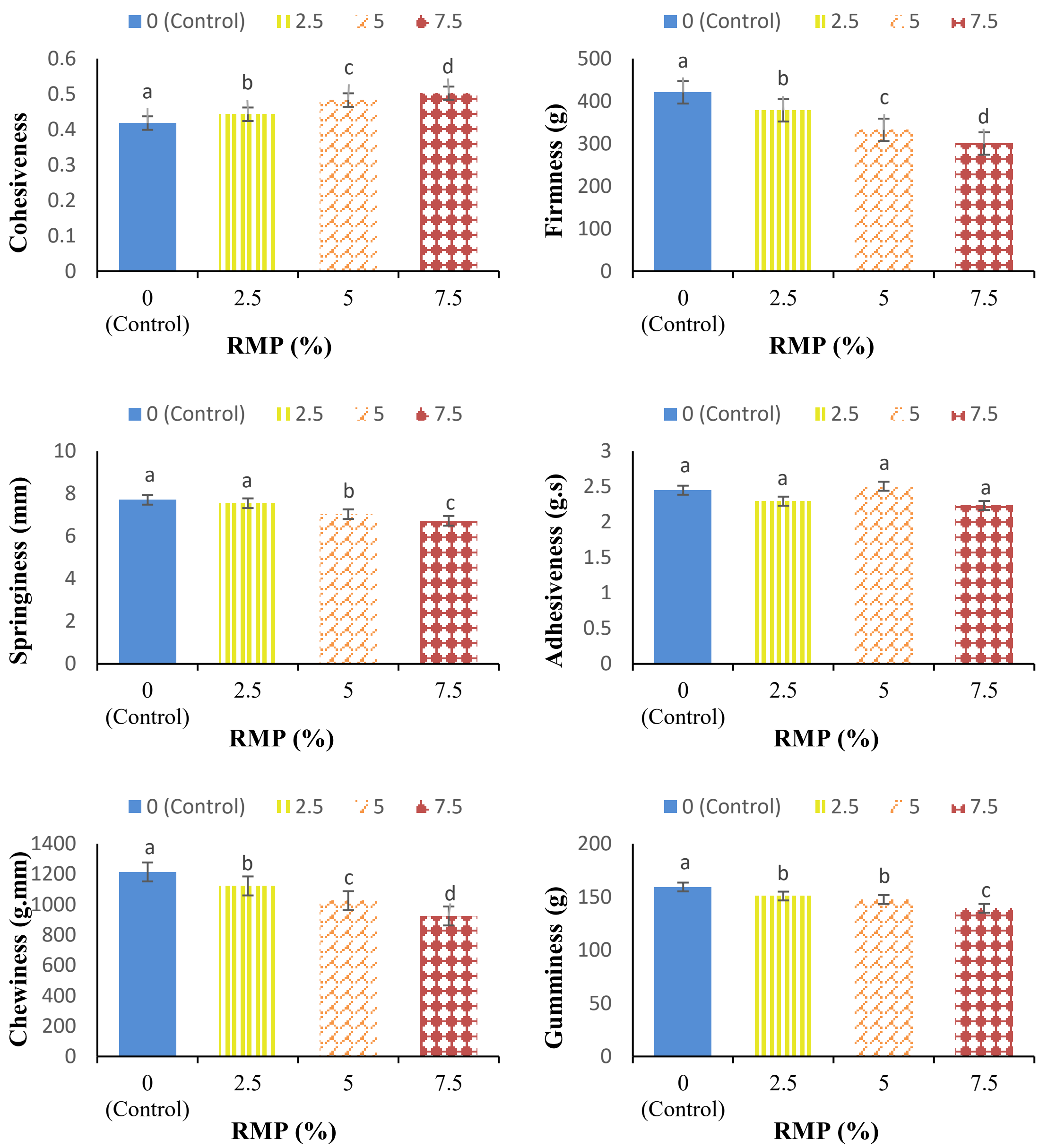

Figure 2. The effect of adding different amounts of rice microgreen powder (RMP) on the textural properties of sponge cake samples during 7 days of storage at ambient temperature.

The results showed that TG enzymatic treatment significantly reduced cake stiffness (364.95 vs. 350.89 g). This is probably due to the increased water retention capacity and the development of the gluten network of the cake through cross-linking between proteins. Alp and Bilgiçli [30] reported similar results on the reduction of cake stiffness in cakes enriched with some types of proteins as a result of TG enzymatic treatment. These researchers used 0.09% enzyme and reported cake stiffness in the control and enzyme-containing samples as 55.43 and

51.40 N on the first day of storage, respectively, and as 61.81 and 58.59 N after 3 days of storage, respectively. However, it should be noted that excessive use of this enzyme can cause tissue compaction and increased stiffness in the product due to excessive intra- and extra-molecular connections between proteins. Dłużewska et al. [31] showed that TG enzymatic treatment with 1 enzyme unit (per gram of protein) reduced the firmness of gluten-free bread, while TG enzymatic treatment with 10 enzyme units significantly increased the firmness of the product. Changes in texture characteristics and density with respect to TG enzyme levels have been previously reported in other food products, such as yogurt [14], traditional white cheese [17] and UF (ultrafiltrated) cheese [32], ice cream [33], and edible film [34], in addition to cake [11].

The results also showed that with the passage of storage time, the firmness of the cake increased significantly. The reason for these changes is stated to be the staleness of the starch-gluten network [18]. Due to the removal of water during the retrogradation process and the reduction of water-starch hydrogen bonds, the role of water as a texture softener decreases.

According to Table 1, among the interactions between the variables tested, only the effect of rice microgreen powder - storage time on firmness was significant. As can be seen in Figure 3-a, the firmness of all cake samples increased significantly after 7 days of storage. The lowest firmness (191.07 g) was for the sample containing 7.5% RMP at the beginning of the storage time and the highest firmness (14.607 g) was for the control sample after 7 days of storage.

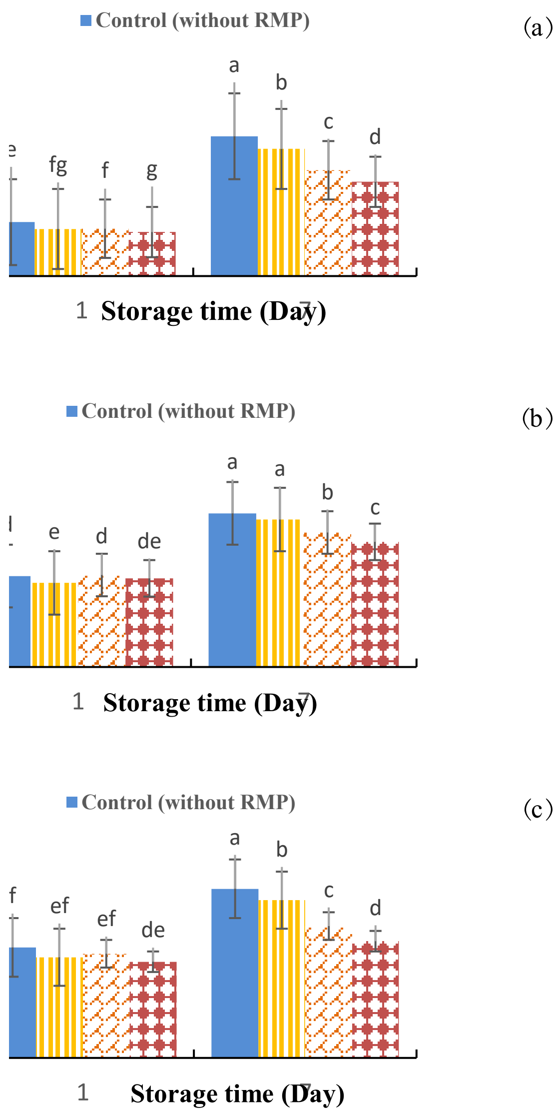

Figure 3. Interaction effect of rice microgreen powder (RMP) and storage time on the firmness (a), gumminess (b) and chewability (c) of sponge cake samples.

The cohesive force can be defined as the maximum resistance measured by the texture measuring device when the probe is removed from the sample, and this force indicates the strength of the internal bonds of the food [35]. According to the results obtained, in addition to stiffness, TG enzymatic treatment and the addition of RMP significantly increased ($p<0.001$) cohesiveness (Table 1). By increasing the amount of rice microgreen powder from 0% to 7.5%, the cohesiveness value increased from 0.42 to 0.50 (Figure 2). Also, TG enzymatic treatment significantly increased cohesiveness, so that samples containing 0.15% enzyme had higher cohesiveness (0.48 compared to 0.44). The increase in texture cohesiveness as a result of TG enzymatic treatment and the addition of RMP can be related to the improvement of the viscoelastic properties of the cake and its greater cohesiveness. Jahanbakhshi and Ansari [18] reported similar results, increasing the cohesiveness of sponge cake along with the increase in olive kernel powder. In contrast to these results, Kim et al. [36] reported a decrease in the cohesiveness of cake as a result of adding *Opuntia humifosa* cactus powder, which was attributed to the lower water absorption capacity of the powder compared to wheat flour. The results also showed that with the passage of storage time, the cohesiveness value of cake decreased significantly ($p<0.001$) and decreased from 0.56 to 0.36. The reason for the decrease in cohesiveness has been attributed to intramolecular interactions and disruption of the cohesiveness of the gluten network of the cake during storage [37]. According to the results of Table 1, the effect of TG enzyme - storage time was significant. The lowest and highest cohesiveness values were observed for the sample without TG enzyme at the end of 7 days of storage (0.35) and the sample containing the enzyme at the beginning of the storage period (0.58), respectively.

Table 1. Analysis of variance (ANOVA) of sensory characteristics of sponge cake samples containing different rice microgreen powder (RMP) and transglutaminase enzyme (TG) during 7 days of storage at 24±1 ◦C.

Treatments	df	Firmness	Cohesiveness	Adhesiveness	Springiness	Gumminess	Chewability
RMP	3	33306.2***	0.017***	0.20NS	2.51***	826.40***	186861.6***
TG	1	2372.3***	0.02***	0.12NS	0.15NS	393.53**	42545.1**
Storage	1	1066256***	0.45***	1.42*	10.07***	53552.3***	1519801.1***
RMP× TG	3	30.88NS	0.00NS	0.15NS	0.01NS	46.29NS	3659.91NS
RMP× Storage	3	16407.9***	0.00NS	0.17NS	0.05NS	971.19***	87958.0***
Storage×TG	1	65.05NS	0.00**	0.04NS	0.01NS	29.57NS	3042.23NS
RMP× TG×Storage	3	17.17NS	0.00NS	0.07NS	0.00NS	16.29NS	889.60NS
Error	32	97.67	0.00	0.24	0.04	45.68	5718.04

NS, *, **, and *** indicate non-significance and significance at the P<0.05, P<0.01, and P<0.001 levels, respectively.

Adhesiveness is defined as the energy required to overcome the attractive force between food molecules and other surfaces [38]. Unlike firmness and cohesiveness, TG enzyme treatment and RMP addition had no effect (p>0.05) on the adhesiveness of cake samples. The adhesiveness of cake samples containing 0 (control) to 7.5% rice microgreen powder was determined to be between 2.50 and 2.23 g/s (Figure 2). Also, the adhesiveness of cake samples containing 0.15% enzyme and without it was determined to be 2.42 and 2.32 g/s. In similar results, Gülhan and Karaça [23] did not observe a significant difference in adhesiveness between gluten-free muffin cake samples containing different levels of 10 to 30% lentil flour. In contrast to the effects of RMP and TG enzyme variables, storage time significantly increased adhesiveness (p<0.05); So that the adhesiveness rate increased from 2.20 g/s on the first day to 2.54 g/s at the end of 7 days of storage. The reason for the increase in adhesiveness of cake samples during storage is related to the release of moisture as a result of the retrogradation of starch chains and its diffusion and absorption on the cake surface [39]. According to the results of Table 1, none of the interaction effects between the 3 variables studied were significant.

Springiness or elasticity is the amount of return of a deformed food to its original state after the force is removed. This property is obtained by considering the distance or height of recovery between the end of the first compression stage and the beginning of the second compression stage. According to the results of this study, the addition of rice microgreen powder and storage time caused a significant ($p<0.001$) decrease in the amount of springiness (Table 1). The decrease in springiness as a result of the addition of RMP can be related to the higher number and larger size of air bubbles in the product [40]. In addition, the decrease in springiness and the elastic property of the cake texture during storage is due to the change in the structure of the gluten network and its weakening. In similar results, Jahanbakhshi and Ansari [18], in investigating the effect of adding olive kernel powder on the textural properties of sponge cake, reported a decrease in springiness when replacing 15 and 25 percent of olive kernel powder with wheat flour in all storage periods. Kim et al. [36] also reported a decrease in cake springiness as a result of the addition of *Cactusapontia humifosa* powder. Also, based on the results obtained, although the addition of TG enzyme somewhat increased the value of this parameter in the samples (7.31 vs. 7.2 mm), these changes were not significant ($p>0.05$). As can be seen in Table 1, here too, none of the interactions between the tested variables were significant.

Gumminess is defined as the force required to break down semi-solid food into a state ready for swallowing, while chewiness is the work required to chew the food in such a way that the material is ready for swallowing. Gumminess is obtained from the product of firmness and cohesiveness, while chewiness is obtained from the product of the three parameters firmness, cohesiveness and springiness [21]. As can be seen in Figure 2, the use of RMP caused a significant decrease in gumminess and chewiness of sponge cake samples ($p<0.001$). The gummy state values of the control cake samples and those containing 7.5% RMP were determined to be 159.34 and 139.28 g, respectively. The chewiness value of the cake with the addition of 7.5% RMP also decreased from 1214.45 to 924.72 g/mm. Similar to the results of the present study, Hosseini ghaboos et al. [41] reported a significant decrease in gumminess and chewiness values in sponge cake samples containing pumpkin flour.

On the other hand, unlike the firmness, TG enzymatic treatment significantly ($p<0.01$) affected the gumminess and chewing resistance of the samples and led to its increase. The average gumminess of the cake increased from 146.39 to 152.11 g/mm with the addition of 0.15% TG enzyme and its chewability increased from 1041.88 to 1101.43 g/mm. As mentioned earlier, the addition of rice microgreen powder and TG enzymatic treatment increases the moisture content of the cake samples; this increase in moisture content can reduce the initial compression resistance and consequently reduce the firmness of the samples. On the other hand, TG enzyme increases the molecular cohesion and elasticity of the protein network by creating crosslinks between proteins. Thus, although the firmness decreases, increasing cohesiveness and elasticity can lead to increased chewability, since chewability is the product of firmness, cohesiveness and elasticity [21]. In other words, increasing moisture softens the surface (less hardness), while factors that increase network cohesion (such as enzymatic treatment with TG) enhance the elasticity and reversibility of the texture. Also, storage time significantly increased the gumminess and chewability (p<0.001); the gumminess of the cake increased from 115.85 g on the first day to 182.65 g on the seventh day. In addition, the average chewability of the cake samples increased from 893.72 g/mm to 1249.60 g/mm on the seventh day. Also, according to Table 1, among the interactions between the variables tested, only the interaction between RMP and storage time was significant. As can be seen in Figure 3, the gummy state and chewiness of all cake samples increased significantly after 7 days of storage. The lowest gummy state (109.53 g) was for the sample containing 2.5% RMP at the beginning of the storage time and the highest gumminess (16.200 g) was for the control sample after 7 days of storage. The lowest chewiness value (835.53 g) was also for the sample containing 7.5% RMP and the highest value (1469.0) was for the control sample at the beginning and end of the storage time, respectively.

3-2- Sensory properties of the cakes

Hedonic or preference method is a suitable and reliable method for evaluating the sensory properties of different foods. Undoubtedly, the sensory properties of foods are the most important factor in consumer product selection. The results of analysis of variance (ANOVA) of the mean scores of sensory properties of sponge cake samples containing different amounts of RMP and TG enzyme during 7 days of storage at room temperature are shown in Table 2 and Figure 4. According to the results of Table 2, except for the appearance of the cake, the addition of rice microgreen powder caused significant changes in the properties under study. In addition, although TG enzyme treatment did not have a significant effect on the sensory properties of the cake samples (p>0.05), all sensory scores underwent significant changes during storage (p<0.001). Also, except for the interaction effect of RMP - storage time on all sensory properties (except for appearance) and TG enzyme - storage time on color property, no significant interaction effect was observed between the variables under study on other sensory properties (Table 2).

Table 2. Analysis of variance (ANOVA) of sensory characteristics of sponge cake samples containing different rice microgreen powder (RMP) and transglutaminase enzyme (TG) during 7 days of storage at 24±1 ◦C.

Treatments	df	Odor	Appearance	Taste	Color	Texture
RMP	3	0.03^{*}	0.00^{NS}	0.18^{**}	0.07^{**}	0.25^{**}

TG	1	0.00^{NS}	0.00^{NS}	0.00^{NS}	0.02^{NS}	0.00^{NS}
Storage	1	25.4^{***}	0.27^{***}	29.8^{***}	0.46^{***}	35.5^{***}
RMP× TG	3	0.01^{NS}	0.00^{NS}	0.01^{NS}	0.01^{NS}	0.01^{NS}
RMP× Storage	3	0.08^{**}	0.01^{NS}	0.04^{*}	0.02^{*}	0.01^{*}
Storage×TG	1	0.00^{NS}	0.00^{NS}	0.02^{NS}	0.01^{**}	0.03^{NS}
RMP× TG×Storage	3	0.01^{NS}	0.00^{NS}	0.02^{NS}	0.02^{NS}	0.00^{NS}
Error	32	0.01	0.02	0.01	0.01	0.00

NS, *, **, and *** indicate non-significance and significance at the P<0.05, P<0.01, and P<0.001 levels, respectively.

As shown in Figure 4, the addition of RMP improved the color, aroma, and texture characteristics of the sponge cake samples, while significantly reducing the taste score of the samples. With the addition of rice microgreen powder, the aroma score increased from 7.48 to 7.54 and the color score from 8.3 to 8.45 in the control and 7.5% RMP samples, respectively. The taste score was also determined as 7.76, 7.61, 7.68, and 7.48 in the control cake and samples containing 2.5, 5, and 7.5% RMP, respectively. However, no significant difference was observed between the 2.5 and 5% RMP levels and the control sample in terms of taste. Similar to the results of this study, Azarhoosh et al. [42] reported a decrease in the taste score of functional cookies due to the addition of wild persimmon juice, and Sobhy et al. [43] reported a decrease in the taste score of sponge cake due to the addition of jojoba flour. In contrast to these results, Ghobadi et al. [44] reported an improvement in the taste of oil cake enriched with 1% blueberry powder and 10% peanut flour, although these researchers reported an improvement in the aroma and texture characteristics, similar to the results of the present study. The reason for the improvement in the texture of sponge cake samples as a result of the addition of rice microgreen powder could be due to the low water absorption capacity of rice microgreen powder compared to wheat flour, which improves the gluten protein network of the dough. In addition, due to the low water absorption capacity of rice microgreen powder, in the final stages of baking the product, the non-bonded water of the cake evaporates more easily and the number and size of pores increase. Therefore, the specific volume of the cake increases and its firmness decreases [26].

Unlike RMP, the addition of TG enzyme had no significant effect on the sensory properties of sponge cake samples (p>0.05). The mean scores for aroma, color, appearance, taste, and texture for the control cake samples were 7.53, 8.33, 8.34, 7.62, and 7.44, respectively, and for cake samples containing 0.15% TG enzyme, they were 7.52, 8.37, 8.33, 7.63, and 7.43, respectively. Dłużewska et al. [31], in their study of the effect of TG enzyme on the quality of gluten-free bread, reported that enzymatic treatment with 1 unit of TG enzyme per gram of protein improved the sensory properties and quality of the cake crust, while treatment with 10 units of TG enzyme per gram of protein significantly reduced the quality of the bread and the textural characteristics of the product. At high enzyme levels, the cake texture is compressed and the product firmness increases due to excessive intra- and extra-molecular cross-linking between proteins.

In addition to the effect of adding RMP, storage time also caused a significant decrease in all sensory scores of the control and enriched sponge cake samples. The average scores of aroma, color, taste and texture of the cake samples at the beginning of the storage time were determined as 8.26, 8.45, 8.42 and 8.30, respectively, which decreased to 6.80, 8.25, 8.85 and 6.58 after 7 days of storage (results not shown). The scores of appearance and texture of the cake samples also decreased significantly ($p<0.05$) during the storage period and were determined as 8.42 and 8.27

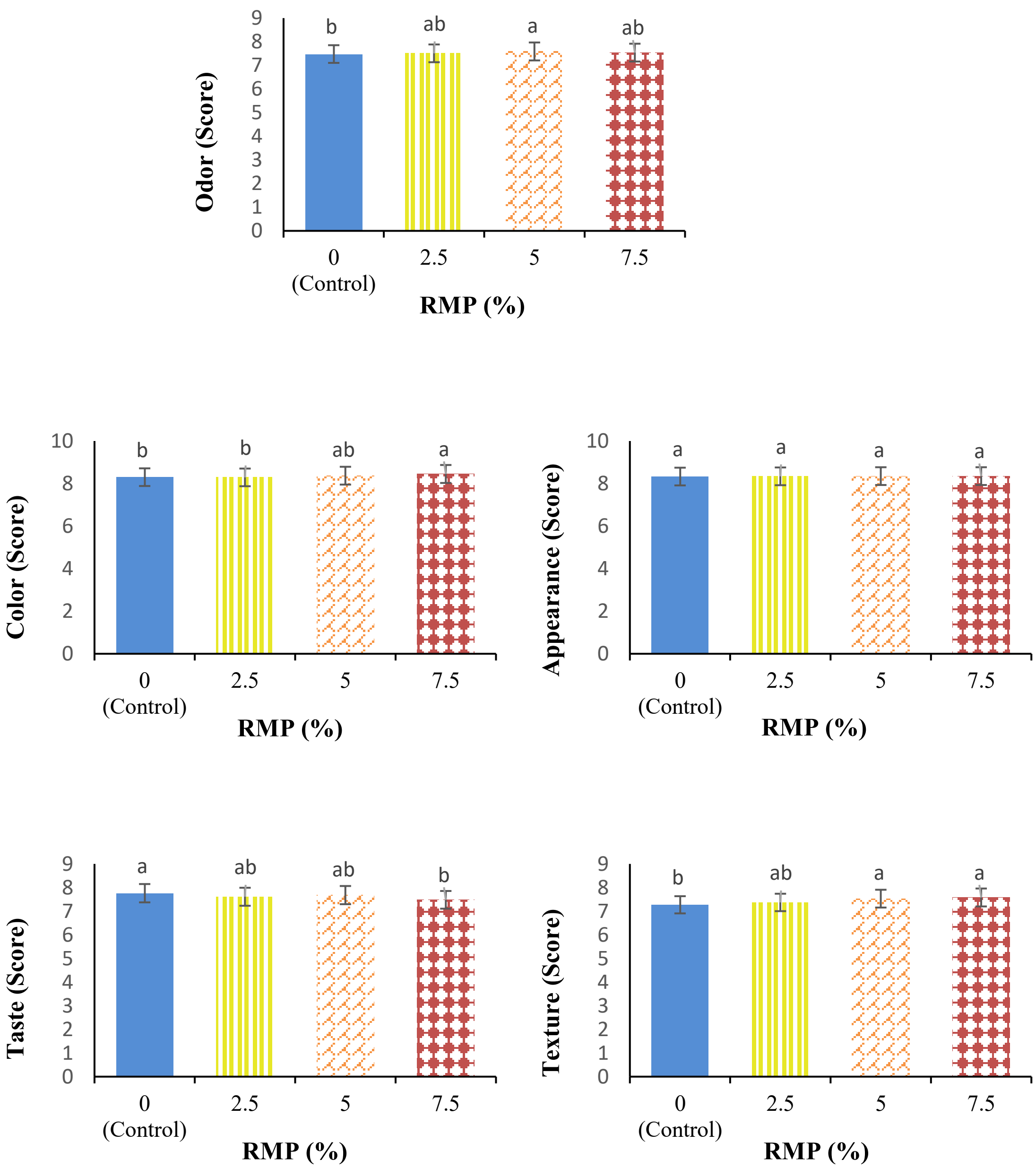

Figure 4. The effect of adding different amounts of rice microgreen powder (RMP) on the sensory properties of sponge cake samples during 7 days of storage at ambient temperature.

at storage periods of 1 and 7 days after production, respectively. The decrease in the sensory score of the cake during storage has also been reported by other researchers [42]. However, all sponge cake samples containing RMP had acceptable sensory scores, and the evaluators gave the samples an average score of acceptable (above 7 or good).

The interaction effect between microgreen powder and storage time on aroma is shown in Figure 5. According to this figure, although there was a significant difference between the aroma of the control sample and the cake samples containing different levels of rice microgreen powder on the first day of storage, no difference was observed at the end of the 7-day storage period. In addition, all samples had a lower aroma score at the end of the 7-day storage period than at the beginning of storage. The highest aroma score (8.37 points) was for the sample containing 5.5% RMP at the beginning of storage and the lowest aroma score (6.75 points) was for the sample containing 7.5% RMP after 7 days of storage. In addition, although a significant difference was observed between the color of the control and the cake sample containing 7.5% RMP at the beginning of the storage period, no difference was observed at the end of the 7-day storage period. The highest odor value (8.6 points) was for the sample containing 7.5% RMP at the beginning of storage and the lowest odor value (8.2 points) was for the sample containing 2.5% RMP after 7 days of storage (Figure 5).

However, unlike the aroma and color results, no significant difference in terms of appearance was observed between the control sample and the cake samples containing different amounts of RMP in both storage periods. In addition, except for the control, the appearance score of all RMP-enriched samples decreased significantly at the end of the storage period. The highest (8.45 points) and lowest (8.2 points) aroma scores were for the sample containing 7.5% RMP at the beginning and end of the storage period, respectively. Regarding taste, the results also showed that although the control sample had a higher taste score than the other enriched samples at the beginning of storage, there was no difference in this respect with the sample containing 5% RMP. At the end of the storage period, no difference in taste was observed between the control sample and the samples containing 5 and 7.5% RMP. The highest (8.37 points) and lowest (6.75 points) taste scores were for the control sample at the beginning and end of the storage period. In addition, as shown in Figure 5, a significant difference was observed between the texture score of the control sample and all cake samples containing different levels of RMP at the beginning of the storage period, but no significant difference was observed with the sample containing 2.5% RMP at the end of the 7-day storage period. In other words, the samples enriched with 5 and 7.5% RMP had significantly higher texture scores than the control sample containing 2.5% RMP in both storage periods and did not differ from each other in this respect.

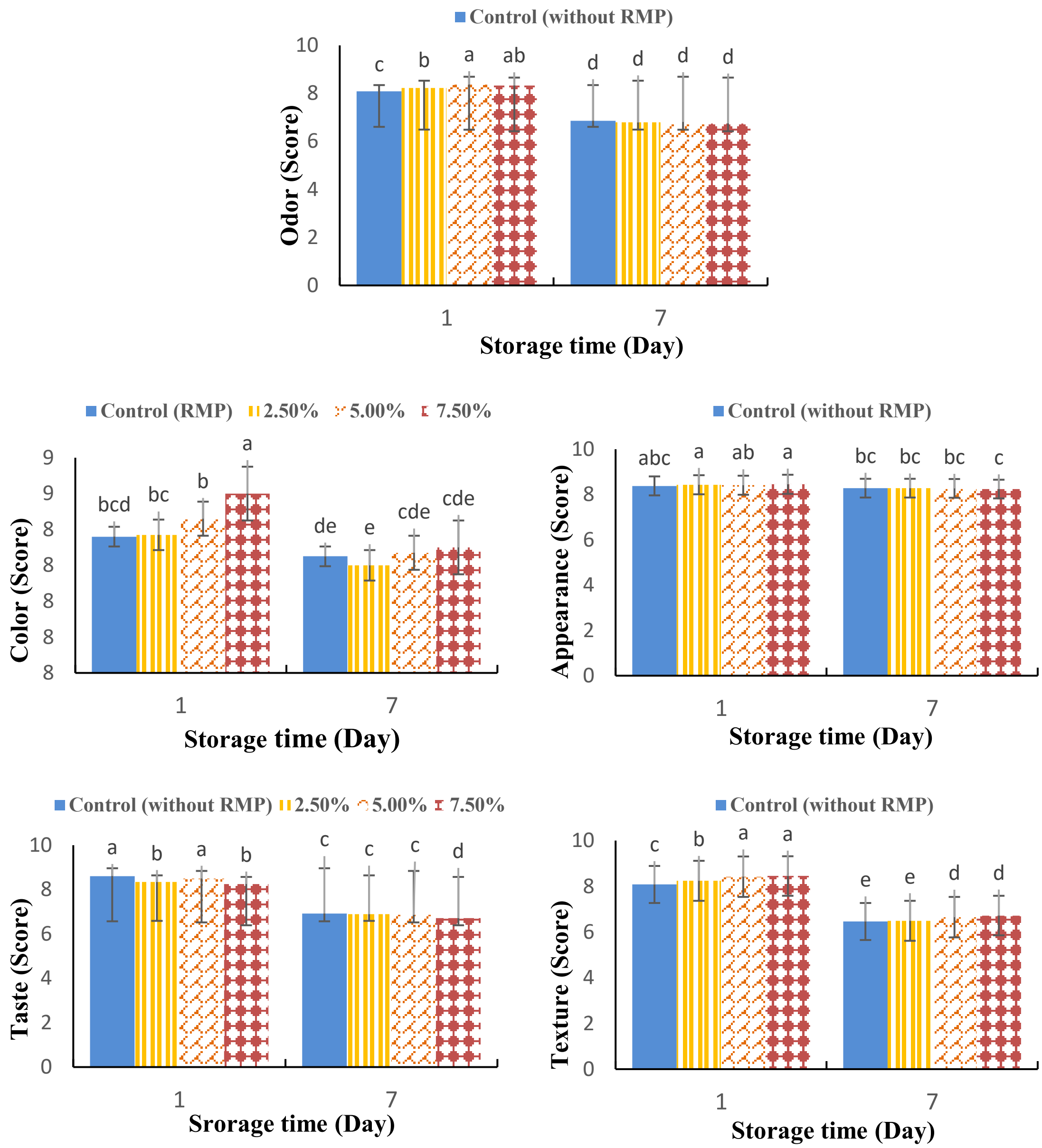

Figure 5- Interaction effect of rice microgreen powder (RMP) and storage time on sensory scores of sponge cake samples.

4- Conclusion

Consumption of bioactive compounds (such as vitamin D, vitamin C, zinc, omega-3, probiotics, and polyphenols) can help reduce the severity and improve clinical outcomes of various diseases such as COVID-19 by improving nutritional status, modulating inflammatory response, and supporting immunity. In addition to their nutritional value, microgreens contain some bioactive compounds that are effective in promoting health and controlling diseases. These bioactive substances are found in various foods, especially grains and vegetables. Since the antioxidant activity of various plants at the microgreen stage is much higher than that of plants at the fully grown stage, microgreens, such as rice microgreens, can be used in fresh or powdered form for food production. Therefore, in this study, the textural characteristics and sensory properties of sponge cake enriched with rice microgreen powder (RMP) along with transglutaminase (TG) enzymatic treatment were investigated in order to produce a product with higher nutritional value and acceptable sensory and textural properties. The results showed that sponge cake samples enriched with RMP had good texture quality and sensory properties. Meanwhile, TG enzymatic treatment was able to maintain the quality of cake texture during storage. Based on the results of this study, adding RMP at levels of 5 to 7.5% along with TG enzymatic treatment is recommended to produce sponge cake with higher nutritional value and at the same time with acceptable sensory properties.

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Data availability

Data will be made available on request.

Conflicts of Interest

The authors declare no conflicts of interest.

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Author Contributions

Hossein Jooyandeh: Conceptualization, Project administration, Investigation, Visualization, Methodology, Software, Validation, Writing – review & editing.
Behrooz Alizadeh Behbahani: Conceptualization, Project administration, Investigation, Visualization, Validation & Writing - original draft.

Sara Saniee: Data collection, Formal analysis, Resources.

6-References

[1] Institute of Standards and Industrial Research of Iran. 2021. Cake –Specifications and Test Methods-Determination of Water Activity and Reference Method. ISIRI, No. 2553. (In Persian)

[2] Guiné, R.P.F., & Florença, S.G. 2024. Development and Characterisation of Functional Bakery Products. Physchem, 4: 234-257.

[3] Humble, N. 2013. Cake: A Global History (Edible). Reaktion Books, 156 pages.

[4] Jooyandeh, H. 2025. Composition of foods and their functions in human nutrition. 1st ed., Khuzestan Agricultural Sciences and Natural Resources University Press. (In Persian)

[5] Jooyandeh, H. 2011. Soy Products as Healthy and Functional Foods. Middle-East Journal of Scientific Research, 7(1): 71-80.
[6] Xiao, Z., Lester, G.E., Luo, Y. & Wang, Q. 2012. Assessment of vitamin and carotenoid concentrations of emerging food products: edible microgreens. Journal of Agricultural and Food Chemistry, 60 (31): 7644-7651.
[7] Dorosh, P.A., & Wailes, E. 2010. The international rice trade: structure, conduct, and performance. In: Rice in the global economy: Strategic research and policy issues for food security. Pandey, S. et al. (ed.), Chapter 3.1: 359-378.
[8] Nooshkam, M., Babazadeh A., & Jooyandeh, H. 2018. Lactulose: Properties, techno-functional food applications, and food grade delivery system. Trends in Food Science & Technology, 80: 23-34.
[9] Momenzadeh, S., Jooyandeh, H., Alizadeh Behbahani, B., & Barzegar, H. 2021. Evaluation of physicochemical and sensory properties of half-fat synbiotic stirred yogurt containing Panirak (*Malva neglecta*) and lactulose. Journal of Food Science and Technology (Iran), 18(120): 353-363. (In Persian)
[10] Asghari-pour, S., Noshad, M., Nasehi, B., Jooyandeh, H., & Beiraghi-Toosi Sh. 2019. Effects of Incorporating Date Kernel Powder on Physicochemical Properties of the Extruded Snacks Containing Corn Flour During Storage. Iranian Journal of Nutrition Sciences & Food Technology, 14(3): e13821: 109-116. (In Persian)
[11] Saeidi, Z., Nasehi, B., & Jooyandeh, H. 2019. Evaluation of Physical properties of gluten-free cake containing pomegranate seeds powder and transglutaminase enzyme. Journal of Food Science and Technology (Iran), 15(84): 315-324. (In Persian)
[12] Jooyandeh, H., Kaur A. & Minhas K.S. 2009. Lipases in dairy industry. Journal of Food Science and Technology, 46(3): 181-189.
[13] Torabi, F., Jooyandeh, H., Noshad, M. & Barzegar, H. 2019. Modeling and Optimization of Physicochemical and Organoleptical Properties and *Lactobacillus acidophilus* Viability in Ultrafiltrated Synbiotic Cheese, Containing Microbial Transglutaminase Enzyme, Whey and Inulin. Research and Innovation in Food Science and Technology, 8(2): 137-150. (In Persian)
[14] Jooyandeh, H., Mahmoodi, R., Samavati, V., & Hojjati, M. 2015. Effect of cold enzymatic treatment of milk by transglutaminase on textural properties of yogurt. Journal of Food Science and Technology (Iran), 13(1): 91-99. (In Persian)
[15] Ege, A.E.R. 2021. The effect of enzyme use on the formation of carbonyls and structural properties of cakes. Dissertation, Master of Science in Biotechnology, Izmir Institute of Technology, Turkey.
[16] Nonaka, M., Tanaka, H., Okiyama, A., Motoki, M., Ando, H., Unda, K., & Matsura, A. 1989. Polymerization of several proteins by Ca^{2+} independent transglutaminase derived from microorganisms. Agricultural and Biological Chemistry, 3: 2619–2623.
[17] Danesh, E., Goudarzi, M. & Jooyandeh, H. 2018. Transglutaminase-mediated incorporation of whey protein as fat replacer into the formulation of reduced-fat Iranian white cheese: physicochemical, rheological and microstructural characterization. Journal of Food Measurement and Characterization, 12: 2416-2425.
[18] Jahanbakhshi, R. & Ansari, S. 2020. Physicochemical Properties of Sponge Cake Fortified by Olive Stone Powder. Journal of Food Quality, 4: 1493638, 1-11.
[19] Saeidi, Z., Nasehi, B., & Jooyandeh, H. 2018. Optimization of gluten-free cake formulation enriched with pomegranate seed powder and transglutaminase enzyme. Journal of Food Science and Technology, 55(8): 3110–3118.
[20] Jooyandeh, H., Minhas K.S. & Kaur A. 2009. Sensory quality and chemical composition of wheat breads supplemented with fermented whey protein concentrate and whey permeate. Journal of Food Science and Technology, 46(2): 146-148.
[21] Jooyandeh, H. 2009. Effect of addition of fermented whey protein concentrate on texture of Iranian white cheese. Journal of Texture Studies, 40: 497-510.
[22] Jooyandeh, H., & Minhas, K.S. 2021. Utilization of fermented whey protein concentrate and whey permeate in beard loaf making. Journal of Food and Bioprocess Engineering, 4(2): 186-192.
[23] Gülhan, M.E., & Karaça, A.C. 2023 Effects of Lentil Flour on the Quality of Gluten-free Muffins. DEÜ FMD, 25(74): 287-302.

[24] Lebesi, D.M., & Tzia, C. 2011. Effect of the addition of different dietary fiber and edible cereal bran sources on the baking and sensory characteristics of cupcakes. Food and Bioprocess Technology, 4: 710-722.
[25] Díaz-Ramírez, M., Calderón-Domínguez, G., García-Garibay, M., Jiménez-Guzmán, J., Villanueva-Carvajal, A. et al. 2016. Effect of Whey Protein Isolate Addition on Physical, Structural and Sensory Properties of Sponge Cake. Food Hydrocolloid, 61: 633–639.
[26] Asif, M., Rooney, L.W., Ali, R., & Riaz, M.N. 2013. Application and opportunities of pulses in food system: a review. Critical Reviews in Food Science and Nutrition, 53(11): 1168-1179.
[27] Shaabani, S., Yarmand, M. S., Kiani, H., & Emam-Djomeh, Z. 2018. The effect of chickpea protein isolate in combination with transglutaminase and xanthan on the physical and rheological characteristics of gluten free muffins and batter based on millet flour. LWT-Food Science and Technology, 90: 362-372.
[28] Moradi, P., Hojjatoleslamy, M., Ahmadi, S.F. (2025) Effect of simultaneous use of fibers on the quality attributes of sponge cake by mixture design approach: Fibers Simultaneous Effect on the Quality of Cake, Food Hydrocolloids for Health, 7: 100203.
[29] Madadi, M., Roshanak, S., Shahidi, F., & Varidi, M.J. 2024. Optimization of a gluten-free sponge cake formulation based on quinoa, oleaster, and pumpkin flour using mixture design methodology. Food Science & Nutrition, 12(4): 2973-2984.
[30] Alp, H., & Bilgiçli, N. 2008. Effect of Transglutaminase on Some Properties of Cake Enriched with Various Protein Sources. Journal of Food Science, 73(5): S209-14.
[31] Dłużewska, E., Marciniak-Lukasiak, K. & Kurek, N. 2015. Effect of transglutaminase additive on the quality of gluten-free bread. Foods, 13(1): 80-86.
[32] Torabi, F., Jooyandeh, H., Noshad, M., & Barzegar, B. 2020. Texture, color and total acceptance of synbiotic ultrafiltrated white cheese treated with microbial transglutaminase enzyme during storage period. Journal of Food Science & Technology (Iran), 17(98): 135-145. (In Persian)
[33] Jooyandeh, H., Danesh, E., & Goudarzi, M. 2017. Effect of microbial transglutaminase on physical, rheological, textural and sensory properties of light ice cream. Iranian Food Science and Technology Research Journal, 13(4): 469-479.
[34] Kouravand, F., Jooyandeh, H., Barzegar, H., & Hojjati M. 2020. Mechanical, barrier and structural properties of whey protein isolate-based films treated by microbial transglutaminase. Journal of Microbiology, Biotechnology and Food Sciences, 9(5): 960-964.
[35] Yademellat, M., Jooyandeh, H., & Hojjati, M. 2016. The effect of application of Persian and Balangu-Shirazi gums on textural properties of low-fat stirred yogurt. Food Research Journal (Iran), 27(4): 171-181. (In Persian)
[36] Kim, J.H., Lee, H.J., Lee, H.S., Lim, E.J., Immd, J.Y., & Suh, H.J. 2012. Physical and sensory characteristics of fibre-enriched sponge cakes made with Opuntia humifusa. LWT - Food Science and Technology, 47: 478e484.
[37] Gularte, M.A., de laHera, E., Go´mez, M., & Rosell, C.M. 2012. Effect of different fibers on batter and gluten-free layer cake properties. LWT-Food Science and Technology, 48: 209–214.
[38] Habibi, S.A., & Jooyandeh, H. 2025. Impact of addition of Persian gum and microbial transglutaminase enzyme on the textural characteristics of semi-fat ultrafiltrated white cheese. Journal of Food Science and Technology (Iran), 21(156): 110-124. (In Persian)
[39] Mortazavinejad, S., Abbasi, H., & Jahadi, M. 2015. Optimization of Sponge Cake Formulation Containing Okara. Research and Innovation in Food Science and Technology, 5(1): 1-14. (In Persian)
[40] Cauvain, S.P. 2020. Breadmaking: Improving Quality, 3rd Edition, Woodhead Publishing Series in Food Science, Technology and Nutrition.
[41] Hosseini ghaboos, S.H., Seyedain Ardabili, S.M., & Kashaninejad, M. 2018. Physico-chemical, textural and sensory evaluation of sponge cake supplemented with pumpkin flour. International Food Research Journal, 25(2): 854-860.
[42] Azarhoosh, Kh., Sharifi, A., & Estiri, S.H. 2017. Studying the effect of replacing sucrose

with wild *Diospyros lotus* pulp on antioxidant properties, phenolic compounds, and sensory and textural characteristics of functional muffins. Journal of Innovation in Food Science and Technology, 9(1): 37-48. (In Persian)

[43] Sobhy, H.M., Gaafar A.M. & El-Anany, A.M. 2015. Nutritional and sensory evaluation of sponge cake incorporated with various levels of Jojoba meal and protein isolate. Advances in Food Sciences, 37(1): 23-30.

[44] Ghobadi, M., Fazeli, F., Mohammadi, H., Zoghi, A., Khorshidian, N., & Mohammadi, M. 2025. Physicochemical, textural and sensorial characteristics of oily cake enriched with Cornelian cherry (*Cornus mas* L.) extract and peanut flour: a valorized food. Applied Food Research, 5(2): 101443.

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مقاله علمی_پژوهشی

تأثیر پودر میکروگرین برنج و آنزیم ترانس‌گلوتامیناز میکروبی بر ویژگی‌های بافتی و حسی کیک اسفنجی در طی دورهٔ نگهداری

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چکیده

کیک‌ها از محصولات پرمصرف فرآورده‌های پخت به شمار می‌روند. مصرف مواد غذایی فراسودمند مانند کیک غنی‌شده می‌تواند نقش مثبتی در سلامت جامعه ایفا کند. در این مطالعه تأثیر افزودن پودر میکروگرین برنج (RMP) در چهار سطح ۰، ۲/۵، ۵ و ۷/۵ درصد (جایگزینی با آرد، وزنی/وزنی) و آنزیم ترانس‌گلوتامیناز (TG) میکروبی در دو سطح ۰، ۰/۱۵ درصد بر ویژگی‌های بافتی و خواص حسی کیک اسفنجی بررسی شد. نتایج نشان داد که افزودن RMP باعث کاهش سفتی، حالت فنریت، صمغی و قابلیت جویدن و افزایش پیوستگی نمونه‌های غنی شدهٔ کیک شد (P<۰/۰۰۱). افزودن TG نیز سبب کاهش معنی‌دار سفتی و افزایش چشمگیر (p<۰/۰۱) پیوستگی، حالت صمغی و مقاومت به جویدن نمونه‌ها شد. زمان نگهداری نیز باعث افزایش سفتی، صمغی و قابلیت جویدن و کاهش پیوستگی و حالت فنریت نمونه‌ها شد (P<۰/۰۰۱). چسبندگی نمونه‌ها نیز تحت تأثیر RMP و آنزیم TG قرار نگرفت اما زمان نگهداری سبب افزایش آن شد (p<۰/۰۵). بررسی خواص حسی نمونه‌ها نیز نشان داد که هرچند تیمار آنزیمی TG تأثیر معنی‌داری بر این ویژگی‌ها نداشت (p>۰/۰۵) اما افزودن RMP سبب بهبود رنگ، رایحه و بافت و کاهش معنی‌دار (P<۰/۰۰۱) امتیاز طعم نمونه‌های کیک اسفنجی گردید. با گذشت زمان نگهداری نیز تمامی خواص حسی کاهش یافت (P<۰/۰۰۱). با توجه به کیفیت بافت و خواص حسی قابل قبول (امتیاز بالاتر از ۷ یا خوب) نمونه‌های غنی شده با RMP، استفاده از آن در سطوح ۵ تا ۷/۵ درصد برای غنی‌سازی کیک اسفنجی همراه با تیمار آنزیمی TG پیشنهاد می‌گردد.