



Journal of Food Science and Technology (Iran)

Homepage: www.fsct.modares.ir

Scientific Research

Modifying the Formulation of Fermented Doughnut with the Aim of Increasing the Quality and Marketability of the Final Product

Mehdi Ghiafeh Davoodi¹, Mahdi Karimi¹, Fariba Naghipour², Alireza Rahmanian³

1- Agricultural Engineering Research Department, Khorasan Razavi Agricultural and Natural Resources Research and Education Center (AREEO), Mashhad, Iran.

2- Seed and Plant Improvement Institute, Agriculture Research, Education and Extension Organization (AREEO), Karaj, Iran

3- Razavi Food Industry Company, Razavi Khorasan, Mashhad, Iran

ARTICLE INFO

ABSTRACT

Article History:

Received: 2026/01/31

Review: 2026/06/06

Accepted: 2026/06/09

Keywords:

Additive,

Starch gelatinization,

Surface active agent,

Fermented doughnut,

Peroxide value.

DOI: 10.48311/fsct.2026.119257.83057

*Corresponding Author E-

Mehdidavoodi@yahoo.com

Staling and moisture loss of bakery products on store shelves is a process that causes high losses to manufacturers. This has led researchers to seek practical solutions to reduce the rate of staleness and, consequently, reduce waste in this category of products. For this purpose, the present study investigated the effect of using a mixture of enzymes (lipase, α -amylase, and xylanase) and a mixture of emulsifiers (DATEM, CITREM, Sodium Stearoyl 2-lactylate (SSL), and Glycerol Monostearate (GMS)) on levels of 0, 0.1, 0.2, and 0.3% on the quantitative and qualitative characteristics of fermented doughnut samples. The results showed that using a mixture of enzymes and emulsifiers increased the moisture content, specific volume, porosity, and decreased the parameters of texture firmness (in both time periods of two hours and 7 days after baking), oil absorption, and peroxide value of the product. However, the results showed that the use of a mixture containing the emulsifiers used increased the amount of the L^* value and decreased the amount of the a^* value of the crust, while the use of a mixture containing the enzymes used decreased the amount of the L^* value and increased the amount of the a^* value of the crust. Therefore, it can be stated that the simultaneous use of an enzyme mixture at a level of 0.2% and an emulsifier mixture at a level of 0.3% leads to improved technological, sensory and shelf-life properties of fermented doughnut. Therefore, it can be said that considering the increasing tendency of producers to export this category of food and create higher added value, the use of the presented formulation increases the shelf life of doughnut, this popular snack.

1- INTRODUCTION

Doughnuts are one of the products derived from wheat flour and are produced in two forms: fermented and non-fermented. The internal structure of the fermented type is very similar to that of semi-voluminous breads and cakes, and the gluten network plays a fundamental role in the quality of this category of products. A fresh doughnut should possess a soft and flexible texture and exude sufficient aroma and flavor. A doughnut consists of two main parts: 1) the fried outer layer and 2) the interior. The fried layer is located on the surface and is in direct contact with the oil. This part experiences the greatest moisture loss and oil absorption, and should ideally have a golden-brown color and a crispy texture. As mentioned, the interior of a doughnut is similar to a cake, and if it receives insufficient heat during frying, starch gelatinization is delayed. The moisture content of the inner part is higher than that of the surface; during storage, this causes moisture to migrate to the fried outer layer [1]. This results in the loss of surface crispness, one of the most important factors leading to consumer rejection and return of the product. Therefore, further studies on the optimal formulation of this product are essential.

To maintain the characteristics of the final product during storage to maximize shelf life, common baking industry additives can be utilized. Emulsifiers are among the most significant compounds in this category; some are added to enhance dough strength, while others are used to increase the softness of the product's crumb. Emulsifiers improve dough properties and enhance crumb freshness due to their ability to bind with gluten [2]. Emulsifiers bind to the hydrophobic surface of proteins, increasing the density of the gluten network in the dough, resulting in a stronger protein network and a higher final product volume [3]. For many years, emulsifiers such as Sodium Stearoyl Lactylate (SSL) and DATEM have been used in the bakery industry as dough conditioners and crumb softeners. Surfactants like SSL can impart strength to the dough [4]. The strengthening effect of SSL on bakery dough is attributed to its reaction with gluten protein during mixing, which may lead to gluten condensation and increased dough stability [5].

Due to the balance in its hydrophilic-lipophilic structure, this emulsifier is widely used in the baking industry. By engaging its lipophilic chain with the hydrophobic domains of gluten protein, SSL enhances dough strength.

In this regard, Van Steertegem *et al.*, (2013) studied the effect of mixing time and the addition of SSL on the polymerization of the gluten network. Their observations indicated that the added ingredients significantly influence the unstable structure of the gluten network during dough mixing and baking. Moreover, the addition of surfactants slows gluten polymerization during heating. Hypothetically, this can be attributed to the interaction between SSL and gliadin, restricting the participation of gliadin in cross-linking. Furthermore, during baking, a portion of the SSL reacts with amylose. These reactions cumulatively contribute to the strength of the baked product's texture [6]. Diacetyl Tartaric Acid Esters of Mono- and Diglycerides (DATEM) and Citric Acid Esters of Mono- and Diglycerides (CITREM) are non-ionic oil-in-water emulsifiers used to improve the quality of baked goods. These emulsifiers are considered dough strengtheners and, when added to the dough, improve mixing tolerance, gas retention, volume, texture, dough resistance, and slicing characteristics [3].

On the other hand, enzymes are biocatalysts increasingly used in the baking industry as natural additives. Enzymes can be used to break down carbohydrates and proteins. Considering the quality of Iranian wheats, the major problem facing the country's flour is its low level of α -amylase activity. Flours with adequate α -amylase activity exhibit better quality and lower staling compared to flour with low amylase activity. If α -amylase activity is extremely low, starch cannot be degraded, leading to the bread becoming hard, firm, and staling faster. Therefore, regulating α -amylase activity is particularly important in fermented and leavened products so the bread maintains its softness and freshness for a long period. Among other enzymes, xylanase, a hydrolyzing enzyme, can be mentioned. This enzyme specifically hydrolyzes arabinoxylan and is widely used in the baking industry [7]. The conversion of unextractable arabinoxylans into extractable arabinoxylans positively impacts baking performance [8]. During this conversion, protein-pentosan networks are

reduced, and bound water is released; this water becomes available to the hydrating gluten, resulting in a softer dough. The newly formed network is more elastic and has an increased water-holding capacity. In this regard, Hardt *et al.*, (2014) studied the effect of water content and xylanase enzyme on the rheology of wheat flour dough and observed that the addition of xylanase increased dough resistance. The hydrolysis of arabinoxylans by xylanase can provide the released water to the gluten, ultimately reducing the amount of additional water needed in the dough [9].

Therefore, based on the aforementioned points, this study aimed to investigate the effect of using a mixture of enzymes and emulsifiers on the quantitative and qualitative characteristics, particularly the staling rate and shelf life, of fermented doughnuts, in order to introduce the best combined formulation for fermented doughnut samples.

2- Materials and Methods

2.1. Materials

Wheat flour (refined flour) used in the preparation of fermented doughnut samples with 12.0% moisture, 11.7% protein, 0.64% ash, and 26.7% wet gluten was obtained from Quds Razavi Flour Factory (Mashhad, Iran). The wheat flour required for the experiments was prepared in one batch and stored in a cold room at 4 °C. Emulsifiers were obtained from Beldem (Belgium), enzymes from DFM (Netherlands), and maltodextrin from Fructose Nab Processing Company (Alborz, Iran). Other materials required for the experiments, including frying oil (Oila, Tehran), skim milk powder, salt, sugar, and eggs, were purchased from a reputable local supplier. All chemicals were also purchased from Merck, Germany. The yeast used in this study (*Saccharomyces cerevisiae*), in the form of active dry yeast in vacuum-sealed packaging, was obtained from Razavi Yeast Company (Mashhad, Iran). It is worth noting that, considering the target market and consumers, which include children, adolescents, and growing individuals, trans-fat-free and cholesterol-free frying oils were used in the formulation at the minimum frying temperature required to produce a healthy product. Other ingredients and materials required for preparation were purchased from confectionery supply stores.

2.2. Methods

2.2.1. Preparation of Fermented Doughnuts

Doughnuts were prepared according to the method of Entezari *et al.*, (2016). The raw materials of the doughnuts included 55% wheat flour, 5% sugar, 10% eggs, 5% oil, 18.5% water, 3% yeast, 0.2% vanilla, 2.8% milk powder, and 0.5% salt. In this study, a mixture of lipase, α -amylase, and xylanase enzymes was used. For this purpose, 100 grams of each enzyme was combined with 700 grams of maltodextrin as a filler. Finally, this mixture was added to the control doughnut formulation at levels of 0, 0.1, 0.2, and 0.3% (based on the total formulation weight). Regarding other additives, each of the emulsifiers DATEM, CITREM, SSL, and GMS were combined in a 1:1:1:1 ratio with respect to each other. Subsequently, this mixture was also added to the control doughnut formulation at levels of 0, 0.1, 0.2, and 0.3% (based on the total formulation weight). After preparing the dough, it was moulded with an outer diameter of 8 cm and an inner diameter of 3 cm and spread to a thickness of 15 mm. The moulded dough was placed in a tray and placed in a hothouse (backcombi model, Miwe, Germany) for 45 mins with 80% relative humidity and a temperature of 43 °C to complete the fermentation period [10]. Then, the doughnut dough samples were fried in a fryer (model DF 2008S, Beem, Germany) at a temperature of 160°C for 6 mins. It is worth noting that, to stabilize the oil temperature, the fryer was turned on one hour before the start of frying, and the fryer tank was filled with two litres of frying oil. At each frying stage, two pieces of dough were placed in the special stainless-steel basket of the device and fried. After half of the frying time had passed, the basket was removed from the device, the doughnuts were turned over, and the other side of the samples was fried. After this step, the samples were placed on absorbent paper to remove excess oil and cooled (for 30 minutes at a temperature of about 25°C), and finally packaged in polyethylene bags and stored at ambient temperature to evaluate quantitative and qualitative characteristics [11].

2.2.2. Evaluation of Quantitative and Qualitative Characteristics of Doughnuts

2.2.2.1. Moisture and Oil

In order to measure the moisture and oil of the produced doughnut samples, the AACC (2000) test was used, with numbers 16-44 and 10-30, respectively [12].

2.2.2.2. Specific Volume

To measure the specific volume of the produced doughnut samples, the volume replacement method with rapeseed was used in accordance with AACC standard No. 10-72. For this purpose, a 25 mm cube was cut from each sample using a serrated knife and weighed, then placed in a cylinder with a specific volume of rapeseed, and the increase in volume was noted. Finally, the specific volume was reported by dividing the volume by the weight of the samples [12].

2.2.2.3. Porosity and Crust Color

The evaluation of the porosity and crust color of the doughnuts was carried out using image processing techniques. Initially, in order to evaluate the porosity, a 25 mm long sample piece was separated by a knife, and images were taken from both sections using a scanner (model: HP Scanjet G3010) with a resolution of 600 pixels and provided to ImageJ software. The porosity of the samples was estimated by calculating the ratio of light to dark spots. Finally, the average porosity calculated for all three sample sections was reported as the final porosity number [13]. Next, to determine the L^* , a^* and b^* values, images were taken from both upper and lower crust using a scanner and the above indices were activated in the Plugins section of the LAB software and the average numbers obtained for the two crusts were reported as color values [14].

2.2.2.4. Firmness of Texture

The firmness of the doughnut texture was evaluated during 2h and seven days after production by using a texture tester (model XT plus, UK). The maximum force required to penetrate a cylindrical probe with a flat end (2 cm diameter x 2.3 cm height) at a speed of 30 mm/min into the sample was calculated as the firmness.

2.2.2.5. Peroxide Value

To measure the peroxide value of the extracted oil from the produced doughnut samples, the Iranian National Standard No. 37 was used [15], and the calculation of the peroxide value of the extracted oil was performed based on Equation 1:

$$P = \frac{1000 \times N \times V}{W}$$

V is the volume of sodium hyposulfite (in mL), N is the normality of the sodium hyposulfite solution, W is the weight of fat in g, and P is the peroxide value in milliequivalents of oxygen per kg of fat.

2.2.2.6. Sensory Evaluation

A 5-point hedonic method (1: very undesirable, 2: undesirable, and... 5: very desirable) was used to evaluate sensory characteristics such as shape and form, porosity, firmness and softness of texture, and smell and taste, which had rank coefficients of 4, 2, 2, and 3, respectively. Each of the doughnut samples was evaluated by 10 judges during 2h after baking. The overall acceptance rate of the produced samples was reported using equation 2.

$$Q = \frac{\sum(P \times G)}{\sum P}$$

Q: overall acceptance, P: trait ranking coefficient, and G: trait evaluation coefficient.

2.2.3. Statistical Design and Method of Analysis of Data

The results obtained from this study were evaluated using SPSS version 16 software. For this purpose, a completely randomized design with a two-factor factorial arrangement was employed. The first factor consisted of different levels of the mixture containing lipase, α -amylase, and xylanase enzymes (0, 0.1, 0.2, and 0.3%). The second factor involved the levels of the mixture containing the emulsifiers DATEM, CITREM, SSL, and GMS (0, 0.1, 0.2, and 0.3%). The samples were prepared in three replications, and the means were compared using Duncan's test at a significance level of 5% ($p < 0.05$). Finally, Excel software was used to draw graphs.

3- Results and Discussion

3.1. Moisture

Figure 1 illustrates the effect of adding different levels of the enzyme mixture (containing lipase, α -amylase, and xylanase at 0, 0.1, 0.2, and 0.3%) and the emulsifier blend (containing DATEM, CITREM, SSL, and GMS at 0, 0.1, 0.2, and 0.3%) on the moisture content of the fermented doughnuts. As shown, the sample containing a combination of 0.2% enzyme mixture and 0.3% emulsifier blend exhibited the highest moisture content ($p < 0.05$).

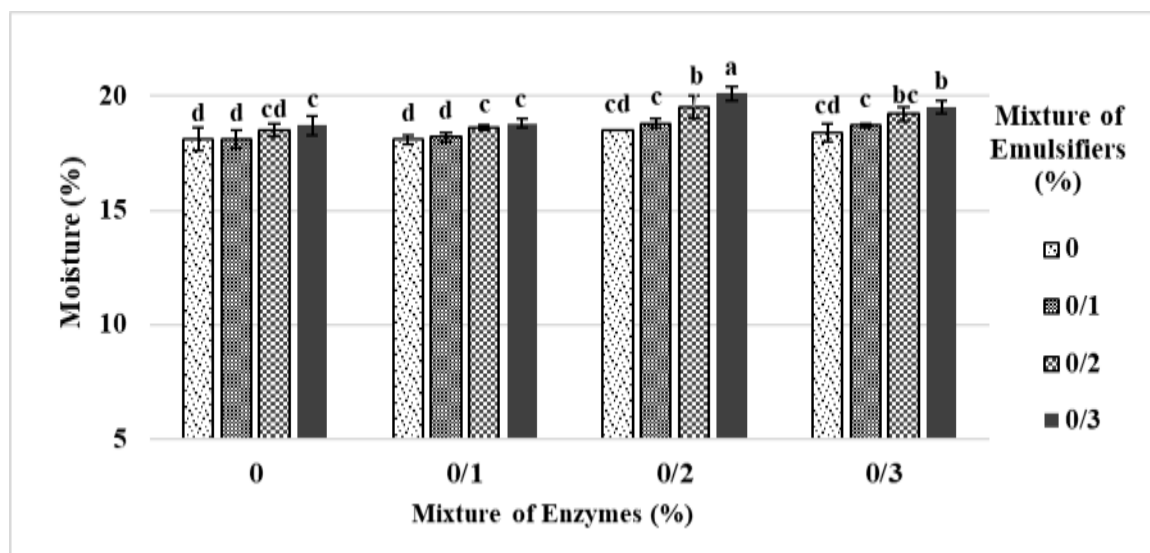


Fig 1. The effect of adding different levels of enzyme and emulsifier mixtures on the moisture content of doughnut

(Means with different letters differ significantly with $p < 0.05$)

Regarding the increase in moisture content in products containing DATEM, Zomorodi and Faramarzi (2020) investigated the effects of flaxseed powder and DATEM emulsifier on the quality and sensory attributes of donuts, reporting that increasing the level of DATEM in the formulation led to an increase in moisture content. They attributed this phenomenon to the ability of emulsifiers to bind water and assist in maintaining product moisture [16]. Similarly, Young (2014) stated that CITREM-based emulsifiers possess the necessary capacity for uniform moisture distribution in bakery products; thus, moisture can be more effectively controlled during expansion and evaporation processes [17]. On the other hand, the current results indicated that the moisture content of the product increased with the use of the enzyme mixture (lipase, α -amylase, and xylanase) up to a level of 0.2%. It appears that exceeding this level (i.e., increasing from 0.2 to 0.3%) leads to excessive starch degradation and structural breakdown, which subsequently diminishes the water-holding capacity of the product. In this regard, Sadeghian Motahar *et al.*, (2021) investigated the improvement of gluten-free bread quality using heat-resistant acid α -amylase (at a concentration of 16 ppm) and reported an increase in product moisture [18].

Furthermore, Dehghan Tanha and Karimi (2016) studied the application of psyllium gum

and fungal α -amylase (at levels of 0, 0.1, and 0.2%) on the physicochemical and sensory properties of donuts, observing that the addition of α -amylase increased the final product's moisture content. They noted that the presence of α -amylase in the dough formulation can increase the amount of damaged starch in wheat flour, which positively impacts the water absorption capacity of the dough and, consequently, the moisture of the final product [19]. Additionally, Rajabzadeh (2010) stated that intact starch granules absorb water equivalent to 30% of their weight at 30°C, whereas damaged starch can absorb 300% or even more [20]. Finally, Mirzaei Tash *et al.*, (2022) examined the effects of adding glucose oxidase, α -amylase, transglutaminase, and xylanase on the rheological properties of Barbari and Lavash bread flour using the response surface methodology, reporting that the addition of xylanase increases the water absorption capacity of the flour [21].

3.2. Oil

The effect of adding different levels of the enzyme mixture (lipase, α -amylase, and xylanase) and the emulsifier blend (DATEM, CITREM, SSL and GMS) on the oil content of the fermented doughnuts showed that the sample containing the combination of 0.2% enzyme mixture and 0.3% emulsifier blend exhibited the lowest oil uptake ($p < 0.05$) (Fig 2)

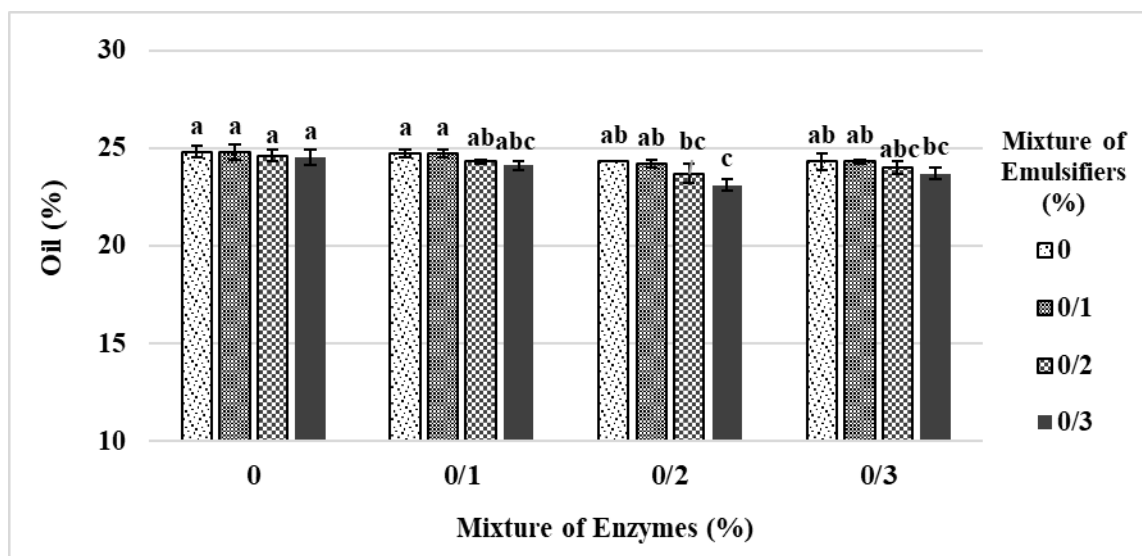


Fig 2. The effect of adding different levels of enzyme and emulsifier mixtures on the oil of doughnut

(Means with different letters differ significantly with $p < 0.05$)

During the frying process, moisture is evaporated from the product, and oil molecules replace the escaping water molecules; consequently, a decrease in moisture content leads to an increase in oil uptake [22, 23]. Regarding the reduction of oil content in the products containing the enzyme and emulsifier blends, it appears that these additives facilitate a reduction in oil uptake by enhancing the moisture content of the final product. Further detailed explanations regarding the increase in moisture content of bakery products through the use of the aforementioned additives have been provided in the moisture content evaluation section.

3.3. Peroxide Value

As shown in Figure 3, the sample containing a combination of 0.2% enzyme mixture and 0.3% emulsifier blend exhibited the lowest peroxide value ($p < 0.05$). In this regard, it should be noted that based on the Iranian National Standard No. 16980, the maximum allowable peroxide value for donuts is 3 mEq/kg.

According to the results, all produced doughnut samples fell within this acceptable standard range [24]. A peroxide value exceeding 6 meq/kg indicates rancidity and renders the product unsuitable for consumption; therefore, controlling and minimizing this parameter is of significant importance. Factors contributing to an increase in the peroxide value include heat exposure, degree of unsaturation, contamination with rancid fat, and presence of air. Given the results from the moisture and oil uptake sections, it was expected that samples with lower oil absorption would exhibit lower peroxide values. As observed, the sample containing the combination of 0.2% enzyme mixture and 0.3% emulsifier blend showed the lowest peroxide value ($p < 0.05$). This is likely because, in this sample, both the amount of absorbed oil is lower, and the higher moisture content potentially delays the increase in the product's core temperature, both of which serve to inhibit the increase in the peroxide value.

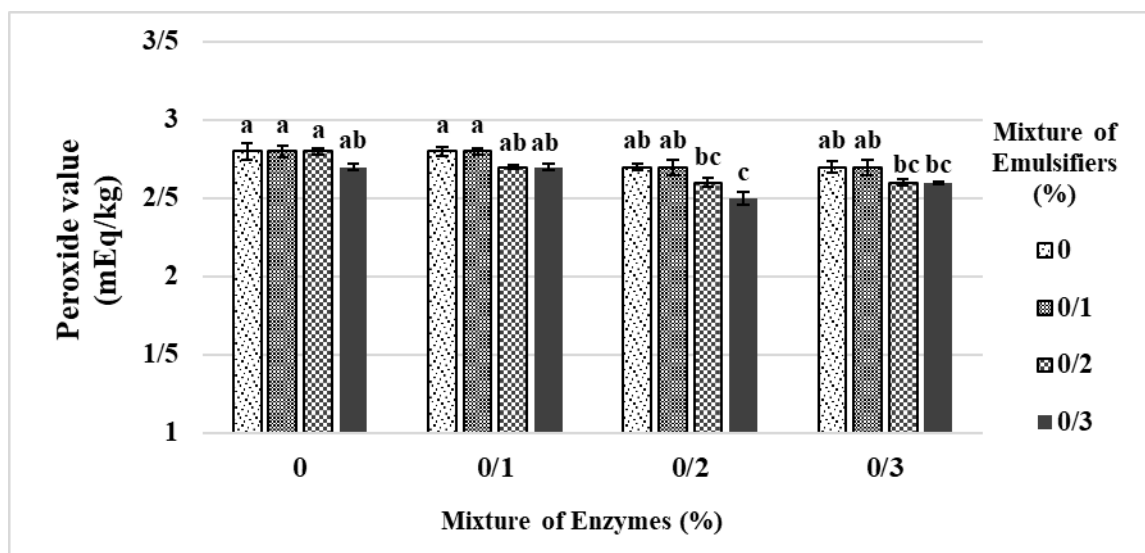


Fig 3. The effect of adding different levels of enzyme and emulsifier mixtures on peroxide value of doughnut

(Means with different letters differ significantly with $p < 0.05$)

3.4. Specific Volume and Porosity

The effects of different levels of the enzyme mixture (lipase, α -amylase, and xylanase) and the emulsifier blend (DATEM, CITREM, SSL and GMS) on the specific volume and porosity

of fermented doughnut are presented in Table 1. As shown, the sample containing a combination of 0.2% enzyme mixture and 0.3% emulsifier blend exhibited the highest specific volume and porosity ($p < 0.05$).

Table 1. The effect of adding different levels of enzyme and emulsifier mixtures on specific volume and porosity of doughnut

Mixture of Enzymes (%)	Mixture of Emulsifiers (%)	Specific volume (ml/g)	Porosity (%)
0	0	3.0 ± 0.10^b	16.7 ± 0.2^c
	0.1	3.0 ± 0.06^b	16.7 ± 0.2^c
	0.2	3.2 ± 0.04^{ab}	16.8 ± 0.0^c
	0.3	3.2 ± 0.05^{ab}	16.8 ± 0.2^c
0.1	0	3.0 ± 0.03^b	16.8 ± 0.2^c
	0.1	3.0 ± 0.04^b	16.9 ± 0.2^c
	0.2	3.2 ± 0.06^{ab}	16.9 ± 0.1^c
	0.3	3.3 ± 0.07^{ab}	17.1 ± 0.2^c
0.2	0	3.2 ± 0.05^{ab}	17.5 ± 0.0^{bc}
	0.1	3.2 ± 0.06^{ab}	17.7 ± 0.2^{abc}
	0.2	3.3 ± 0.04^{ab}	18.0 ± 0.3^{ab}
	0.3	3.5 ± 0.08^a	18.4 ± 0.3^a
0.3	0	3.2 ± 0.02^{ab}	17.4 ± 0.4^{bc}
	0.1	3.3 ± 0.05^{ab}	17.5 ± 0.1^{bc}
	0.2	3.3 ± 0.04^{ab}	17.7 ± 0.3^{abc}
	0.3	3.2 ± 0.06^{ab}	18.0 ± 0.3^{ab}

Data are in the form of average $\pm$ Standard deviation.

Different letters in each column have significant differences with $p < 0.05$ statistically.

Brooker (2003) stated that the addition of emulsifiers to baked products promotes a more

uniform distribution of air cells, improves the volume and texture of the final product, and delays staling [25]. In this regard, Zomorodi

and Faramarzi (2020), in evaluating the effects of flaxseed powder and DATEM emulsifier on the quality and sensory properties of doughnuts, reported that increasing the amount of DATEM in the formulation led to an increase in specific volume. They explained that DATEM emulsifier promotes a proper distribution of air particles in the cake batter, thereby increasing batter viscosity, which in turn results in improved volume and texture in the final product [16]. Likewise, Young (2014) reported that citrate-based emulsifiers can reduce interfacial tension. Therefore, water in the system still converts into steam, but it does not “explode” because it can escape under much more controlled conditions [17].

The results also showed that by increasing the enzyme blend level from 0.2 to 0.3%, the ability of the product to retain and stabilize air bubbles decreased, owing to the greater extent of starch degradation, and consequently the specific volume and porosity were reduced. In this regard, Sadeghian Motahar *et al.*, (2021) investigated the improvement of gluten-free bread quality by means of a heat-stable acid α -amylase and reported that the specific volume of the product increased when this enzyme was used. They attributed this effect to two factors. First, the presence of α -amylase increases the formation of reducing sugars, which are subsequently consumed by microorganisms during fermentation, leading to greater gas production. Second, α -amylase activity reduces dough viscosity during starch gelatinization, thereby prolonging oven spring [18]. Rocchia *et al.*, (2012) also studied the effects of various

enzymes on wheat–soy dough properties and bread quality and found that the highest specific volume was achieved at a xylanase concentration of 0.012%. They stated that this increase was probably due to the effect of the enzyme on water absorption, increased dough viscosity, redistribution of bound water among flour components such as gluten, and consequently on the viscoelastic properties of the dough, which resulted in a higher specific volume [26]. Studies have also been conducted on the effect of lipase on specific volume. In this regard, Pashaei *et al.*, (2025) examined the role of enzymes in gluten-free bakery products and reported that lipase-induced changes in lipid polarity increased the stability of gas cell walls, which in turn enhanced the stability of baked products. They also stated that lipases are suitable alternatives to emulsifiers in gluten-free bakery products because they reduce hardness while improving porosity and increasing loaf volume [27].

3.5. Crust Color

As shown in Table 2, the sample containing a combination of 0% enzyme mixture and 0.3% emulsifier mixture exhibited the highest L* value ($p < 0.05$). Furthermore, the highest a* value was observed in the sample containing a combination of 0.3% enzyme mixture and 0% emulsifier mixture. Ultimately, the addition of the compounds did not have a significant effect on the b* value of the fermented doughnut ($p < 0.05$).

Table 2. The effect of adding different levels of enzyme and emulsifier mixtures on crust color values of doughnut

Mixture of Enzymes (%)	Mixture of Emulsifiers (%)	Crust color values (-)		
		L*	a*	b* ^{ns}
0	0	46.2±0.5 ^{bc}	14.9±0.2 ^{bc}	21.4±0.3
	0.1	46.1±0.4 ^{bc}	14.8±0.3 ^{bc}	21.3±0.2
	0.2	47.3±0.5 ^b	14.8±0.2 ^{bc}	21.5±0.0
	0.3	49.8±0.6 ^a	14.3±0.1 ^d	21.3±0.3
0.1	0	46.0±0.5 ^{bc}	15.0±0.2 ^{bc}	21.4±0.1
	0.1	46.2±0.4 ^{bc}	14.9±0.2 ^{bc}	21.5±0.5
	0.2	47.3±0.7 ^b	14.9±0.1 ^{bc}	21.5±0.3
	0.3	47.0±0.2 ^b	14.6±0.2 ^{dcd}	21.5±0.4
0.2	0	44.1±0.0 ^{bcd}	15.6±0.2 ^{ab}	21.5±0.2
	0.1	44.2±0.7 ^{bcd}	15.5±0.0 ^{ab}	21.4±0.4
	0.2	45.3±0.6 ^{bcd}	15.3±0.0 ^{abc}	21.3±0.2
	0.3	45.4±0.5 ^{bcd}	15.0±0.3 ^{bc}	21.5±0.0

0.3	0	42.2±0.4 ^d	16.2±0.3 ^a	21.6±0.5
	0.1	43.7±0.5 ^{cd}	15.8±0.2 ^{ab}	21.3±0.4
	0.2	43.7±0.3 ^{cd}	15.7±0.1 ^{ab}	21.5±0.5
	0.3	44.1±0.3 ^{cd}	15.6±0.3 ^{ab}	21.4±0.3

Data is in the form of average ± Standard deviation.

Different letters in each column have significant differences with $p<0.05$ statistically.

ns: No significant difference with $p<0.05$

It appears that the use of the aforementioned enzymes causes the breakdown of starch compounds and triglycerides and their conversion into simpler sugar and lipid compounds, which consequently intensifies the Maillard reaction. On the other hand, the use of the mixture containing the emulsifiers employed in this study resulted in slower moisture loss from the surface of the donut during the frying process. Consequently, the product developed a more uniform surface. Regarding the increase in the L^* value of the product containing the emulsifier DATEM, Zomorodi and Faramarzi (2020), in their study investigating the effects of flaxseed powder and DATEM emulsifier on the quality and sensory characteristics of doughnuts, reported that increasing the level of DATEM emulsifier in the product formulation increased the L^* value. They attributed this finding to the ability of these compounds to retain moisture and slow its release from the product [16]. Similarly, Kim and Walker (1992) attributed the reduction in

the a^* value resulting from the use of DATEM emulsifier to its ability to homogenize the dough and produce very fine emulsion droplets, thereby causing dough whitening [28]. Studies have also investigated the increase in the a^* value of products in the presence of the enzyme mixture used in this study. In this regard, Sadeghian Motahar *et al.*, (2021) investigated the improvement of gluten-free bread quality using heat-stable acid-resistant alpha-amylase and reported that the a^* value of the product increased with the use of this enzyme. They attributed this effect to the greater production of reducing sugars and the intensification of the Maillard reaction [18].

3.6. Firmness of Texture

Table 3 presents the effect of the added levels of enzyme and emulsifier blends on the texture hardness of fermented doughnuts at two-time intervals: two hours and seven days after baking. As shown, the sample containing a combination of 0.2% enzyme mixture and 0.3% emulsifier blend exhibited the lowest texture hardness at both time intervals ($p<0.05$).

Table 3. The effect of adding different levels of enzyme and emulsifier mixtures on firmness of fermented doughnut during storage

Mixture of Enzymes (%)	Mixture of Emulsifiers (%)	Firmness (N)	
		2h after baking	7 days after baking
0	0	21.4±0.5 ^a	30.3±0.3 ^a
	0.1	21.3±0.4 ^a	30.0±0.0 ^a
	0.2	20.4±0.5 ^{ab}	28.8±0.2 ^{ab}
	0.3	19.7±0.2 ^{ab}	26.4±0.4 ^{bc}
0.1	0	21.1±0.3 ^a	30.0±0.2 ^a
	0.1	21.7±0.3 ^a	28.9±0.2 ^{ab}
	0.2	18.9±0.2 ^b	27.8±0.0 ^b
	0.3	17.3±0.2 ^{bc}	26.0±0.5 ^{bc}
0.2	0	19.9±0.1 ^{ab}	29.4±0.3 ^{ab}
	0.1	19.4±0.0 ^{ab}	28.3±0.0 ^b
	0.2	17.1±0.3 ^{bc}	26.5±0.1 ^{bc}
	0.3	15.4±0.2 ^c	24.2±0.0 ^c
0.3	0	20.1±0.2 ^{ab}	29.1±0.1 ^{ab}

0.1	19.8±0.4 ^{ab}	28.7±0.5 ^{ab}
0.2	18.4±0.3 ^b	27.5±0.2 ^b
0.3	17.5±0.1 ^{bc}	25.9±0.3 ^{bc}

Data is in the form of average ± Standard deviation.

Different letters in each column have significant difference with $p<0/05$ statistically.

In general, preventing moisture loss, especially during storage, plays a vital role in maintaining the freshness of bakery product texture. Furthermore, staling in bakery products, such as bread and fermented doughnuts, is closely associated with moisture content and the functionality of water within the crumb [29]. Since higher water availability to starch increases the probability of starch crystallization, the strong water-binding capacity of humectants reduces the amount of water available to starch. Consequently, this leads to reduced starch swelling and gelatinization, as well as delayed recrystallization (retrogradation) during storage, ultimately reducing firmness and delaying product staling [30]. In the current study, based on the moisture and specific volume evaluations, it was evident that the addition of the aforementioned compounds resulted in a decrease in the final product's texture hardness. As observed, the sample containing a combination of 0.2% enzyme mixture and 0.3% emulsifier blend exhibited the lowest texture hardness ($p<0.05$). In this regard, Demirkesen *et al.*, (2010) evaluated the effect of various gums (guar, xanthan, locust bean, HPMC, pectin) and DATEM emulsifier on the rheological properties of gluten-free rice flour-based bread. Their results indicated that the lowest crumb firmness was observed in samples containing gums and DATEM, which

they attributed to increased moisture content and enhanced gas retention capacity during fermentation [31]. Moreover, Young (2014) reported that comparative studies using three commercial monoglyceride types (plastic, hard hydrated, and soft distilled monoglycerides) showed that, at equivalent α -monoglyceride levels, all three forms are equally effective in retarding crumb firming [17]. Dahiya *et al.*, (2020) investigated the biotechnological potential of various enzymes in bread making, stating that xylanase modifies dough rheological properties by converting water-insoluble hemicelluloses into soluble forms, thereby reducing hardness, increasing specific volume, and enhancing the quality, nutritional, and sensory properties of gluten-free bread [32]. Regarding lipase, studies suggest that its effect on reducing hardness is primarily due to the mitigation of starch retrogradation through the hydrolysis of di- and triglycerides into anti-staling monoglycerides [33]. Pashaei *et al.*, (2025) also noted that lipases are suitable alternatives to emulsifiers in gluten-free bakery products, as they reduce hardness by improving porosity while simultaneously increasing bread volume [27].

3.7. Sensory Evaluation

As shown by the results (Fig 4), the sample containing a combination of 0.2% enzyme mixture and 0.3% emulsifier mixture had the highest overall acceptability score ($p<0.05$).

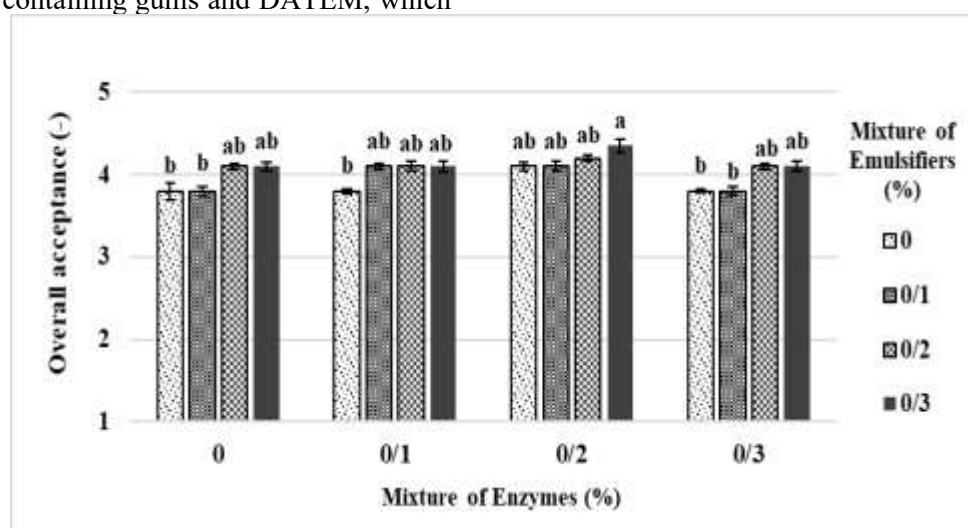


Fig 4. The effect of adding different levels of enzyme and emulsifier mixtures on overall acceptance of doughnut**(Means with different letters differ significantly with $p < 0.05$)**

A doughnut consists of two parts: an outer and an inner portion. The outer portion, which is located at the surface, is fried and comes directly into contact with the oil. This portion experiences the greatest moisture loss and oil uptake and, ideally, has a golden-brown colour and a crisp texture. The inner portion is cake-like, and if it does not receive sufficient heat during frying, starch gelatinization is delayed. Consequently, the moisture content in this portion remains higher than at the surface, causing moisture to migrate toward the fried portion during storage and resulting in the loss of surface crispness [34]. Therefore, considering the aforementioned points as well as the importance of moisture retention within the structure, it is evident that having a smooth surface along with a texture characterized by desirable volume and porosity is of considerable importance to consumers and sensory panellists. Accordingly, a sample exhibiting these desirable quantitative and qualitative characteristics is expected to receive a high score in sensory evaluation.

4- Conclusion

Based on the results, it was found that the use of a mixture of enzymes and emulsifiers in the formulation of fermented doughnuts increased moisture content, specific volume, and porosity, while reducing texture firmness parameters (at both 2 hours and 7 days after baking), oil uptake, and peroxide value of the product. On the other hand, the results showed that the use of the emulsifier mixture increased the L^* value and decreased the a^* value of the crust, whereas the use of the enzyme mixture decreased the L^* value and increased the a^* value of the crust. Therefore, based on the aforementioned findings, it can be concluded that the simultaneous use of the enzyme mixture, containing lipase, α -amylase, and xylanase, at a level of 0.2%, and the emulsifier mixture, containing DATEM, CITREM, SSL and GMS, at a level of 0.3%, improved the technological, sensory, and shelf-life characteristics of fermented doughnuts, and this formulation was selected as the best sample. Therefore, with minor modifications to the formulation, in addition to extending shelf

life and facilitating the development of domestic and export markets for this popular and relatively inexpensive snack, the amount of product waste and returns can also be reduced.

Data Availability

The data that support the findings of this study are available on request from the corresponding author.

Conflict of Interest

The authors have no conflicts of interest to declare.

Funding Statement

This research was supported by Agricultural Engineering Research Department, Khorasan Razavi Agricultural and Natural Resources Research and Education Center (AREEO) and Razavi Food Industry Company.

Authors Contributions

Methodology: Mehdi Ghiafeh Davoodi, Mahdi Karimi and Alireza Rahmanian; Writing – original draft: Mehdi Ghiafeh Davoodi and Fariba Naghipour; Data Analysis: Fariba Naghipour; Writing – Review and editing: Mehdi Ghiafeh Davoodi.

AI statement

Approximately a 20–35% likelihood of AI involvement in the writing and editing process (low to moderate).

5- References

- [1] Salim, R., and Aliistair, P. 2007. Influence of partial substitution of wheat flour with vetch flour on quality characteristics of doughnuts. *LWT- Food Science and Technology*, 40: 73-82.
- [2] Colakoglu, A.S., and Ozkaya, H. 2012. Potential use of exogenous lipases for DATEM replacement to modify the rheological and thermal properties of wheat flour dough. *Journal of Cereal Science*, 55: 397-404.
- [3] Ribotta, P.D., Perez, G.T., Leona, A.E., and Anon, M.C. 2004. Effect of emulsifier and guar gum on micro structural, rheological and baking performance of frozen bread dough. *Food Hydrocolloids*, 18: 305–313.
- [4] Pareyt, B., Finnie, S.M., Putseys, J.A., and Delcour, J.A. 2011. Lipids in bread making: Sources, interactions, and impact on bread quality. *Journal of Cereal Science*, 54: 266–279.

- [5] Gomez, A.V., Ferrer, E.G., Anon, M.C., and Puppo, M.C. 2013. Changes in secondary structure of gluten proteins due to emulsifiers. *Journal of Molecular Structure*, 1033: 51–58.
- [6] Van Steertegem, B., Pareyt, B., Brijs, K., Delcour, J.A. 2013. Impact of mixing time and sodium stearoyl lactylate on gluten polymerization during baking of wheat flour dough. *Food Chemistry*, 141: 4179–4185.
- [7] Verjans, P., Dornez, E., Delcour, J.A., and Courtin, C.M. 2010. Selectivity for water unextractable arabinoxylan and inhibition sensitivity govern the strong bread improving potential of an acidophilic GH11 *Aureobasidium pullulans* xylanase. *Food Chemistry*, 123 (2): 331–337.
- [8] Goesaert, H., Gebruers, K., Courtin, C.M., Brijs, K., and Delcour, J.A. 2006. Enzymes in breadmaking. *Bakery Products: Science and Technology*, Ames, Iowa, USA: Wiley-Blackwell Publishing Professional, 337–364.
- [9] Hardt, N.A., Boom, R.M., and van der Goot, A.J. 2014. Wheat dough rheology at low water contents and the influence of xylanases. *Food Research International*, 66: 478–484.
- [10] Entezari, B., Karzhan, H., and Sharifi, A. 2016. Studying the effect of Chobak extract on antioxidant properties and shelf life of doughnut. *Journal of Innovation and Technology in Food Science and Industry*, 1(9): 27–40 [in Persian].
- [11] Dehghan Tanha, L., Karimi, M. and Salehifar, M. 2013. The effect of emulsions and lipase on the qualitative properties of frozen doughnut. *Journal of Innovation and Technology in Food Science and Technology*, 5(3): 105–115 [in Persian].
- [12] AACC. 2000. Approved Methods of the American Association of Cereal Chemists, 10th Ed., Vol. 2. *American Association of Cereal Chemists*, St. Paul, MN.
- [13] Haralick, R.M., Shanmugam, K., and Dinstein, I. 1973. Textural features for image classification. *IEEE Transactions of ASAE*, 45(6): 1995–2005.
- [14] Sun, D. 2008. Computer vision technology for food quality evaluation. Academic Press, New York.
- [15] Anonymous. 2019. Biscuit- Specifications and test methods. Iranian National Standardization Organization, No 37 [in Persian].
- [16] Zomorodi, Sh., and Faramarzi, S. 2020. The effect of flaxseed powder (*linum usitalissimum*) and DATEM as emulsifier on the qualitative and sensory properties of doughnut. *Journal of Food Researches*, 30(1): 99–111 [in Persian].
- [17] Young, N.W.G. 2014. Emulsifiers and stabilizers. *Fats in Food Technology*, Second Edition. Chapter 7: 253–287.
- [18] Sadeghian Motahar, S.F., Ariaenejad, S., Salami, M., Emam-Djomeh, Z., and Sheykh Abdollahzadeh Mamaghani, A. 2021. Improving the quality of gluten-free bread by a novel acidic thermostable α -amylase from metagenomics data. *Food Chemistry*, 352 (129307).
- [19] Dehghan Tanha, L., and Karimi, M. 2016. Application of Plantago gum and fungal α -amylase enzyme on Physicochemical and organoleptic properties of doughnut. *Journal of Food Science and Technology*, 13(52):101–110 [in Persian].
- [20] Rajabzadeh, N. 2010. Bread Technology. 2nd edition. University of Tehran Publishing Institute [in Persian].
- [21] Mirzaei tash, O., Gharekhani, M., Mirzaei, H., and Javadi, A. 2022. Investigating the effects of adding glucose oxidase, α -amylase, transglutaminase and xylanase enzymes on the rheological properties of barbary and lavash flour using the response surface method. *Journal of Food Science and Technology*, 19(131):131–142 [in Persian].
- [22] Ananey-Obiri, D., Matthews, L., Azahrani, M.H., Ibrahim, S.A., Galanakis, C.M., and Tahergorabi, R. 2018. Application of protein based edible coatings for fat uptake reduction in deep-fat fried foods with an emphasis on muscle food proteins. *Trends in Food Science and Technology*, 80: 167–174.
- [23] Liberty, J.T., Dehghannya, J., and Ngadi, M.O. 2019. Effective strategies for reduction of oil content in deep-fat fried foods: A review. *Trends in Food Science and Technology*, 92: 172–183.
- [24] Anonymous. 2013. Doughnut- Specifications and test methods. Iranian National Standardization Organization, No 16980 [in Persian].
- [25] Brooker, B.E. 2003. The stabilisation of air in cake batters-the role of fat. *Food Structure*, 12: 285–296.

[26] Roccia, P., Ribotta, P.D., Ferrero, C., Pérez, G.T., and León, A.E. 2012. Enzymes Action on Wheat–Soy Dough Properties and Bread Quality. *Food Bioprocess Technology*, 5: 1255–1264.

[27] Pashaei, M., Bahmanyar, F., Tahmouzi, S., Sanaei Nasab, S., Khalili Sadrabad, E., Mollakhalili-Meybodi, N., and Mirmoghtadaie, L. 2025. The role of enzymes in gluten-free bakery products: A review of technological and nutritional perspectives. *Applied Food Research*, 5(1): 100923.

[28] Kim, C.S., and Walker, C.E. 1992. Effects of sugars and emulsifiers on starch gelatinization evaluated by differential scanning calorimetry. *Cereal Chemistry*, 69: 212-217.

[29] Zeleznak, K.J., and Hoseney, R.C. 1986. The role of water in the retrogradation of wheat starch gels and bread crumb. *Cereal Chemistry*, 63 (5): 407-411.

[30] Vittadini, E., and Vodovotz, Y. 2003. Changes in the physicochemical properties of wheat and soy-containing breads during storage as studied by thermal analyses. *Food Engineering and Physical Properties*, 68: 2022-2027.

[31] Demirkesen, I., Mert, B., Sumnu, G., and Sahin, S. 2010. Rheological properties of gluten-free bread formulation. *Journal of Food Engineering*, 96: 295-303.

[32] Dahiya, S., Bajaj, B.K., Kumar, A., Tiwari, S. K., and Singh, B. 2020. A review on biotechnological potential of multifarious enzymes in bread making. *Process Biochemistry*, 99: 290–306.

[33] Castello, P., Potus, J., Baret, J.L., and Nicolas, J. 1999. Effects of mixing conditions and wheat flour dough composition on lipid hydrolysis and oxidation levels in the presence of exogenous lipase. *Cereal Chemistry*, 76: 476-482.

[34] Tan, K.J., and Mittal, G.S. 2006. Physicochemical properties changes of donuts during vacuum frying. *International Journal of Food Properties*, 9(1): 85-98.



اصلاح فرمولاسیون دونات تخمیری با هدف افزایش کیفیت و بازارپسندی محصول نهایی

مهدی قیافه داودی^۱، مهدی کریمی^۱، فریا نقی پور^۲، علیرضا رحمانیان^۳

۱- بخش تحقیقات فنی و مهندسی کشاورزی، مرکز تحقیقات و آموزش کشاورزی و منابع طبیعی استان خراسان رضوی، سازمان تحقیقات، آموزش و ترویج کشاورزی، مشهد، ایران

۲- مؤسسه تحقیقات اصلاح و تهیه نهال و بذر، سازمان تحقیقات، آموزش و ترویج کشاورزی، کرج، ایران

۳- شرکت صنایع غذایی رضوی، خراسان رضوی، مشهد، ایران

اطلاعات مقاله

چکیده

تاریخ های مقاله :

تاریخ دریافت: ۱۴۰۴/۱۱/۲۱

تاریخ داوری: ۱۴۰۵/۰۳/۱۶

تاریخ پذیرش: ۱۴۰۵/۰۳/۱۹

کلمات کلیدی:

افزودنی،

ژلاتیناسیون نشاسته،

ترکیبات فعال سطحی،

دونات تخمیری،

اندیس پراکسید.

DOI:10.48311/fsct.2026.119257.83057

* مسئول مکاتبات:

Mehdidavoodi@yahoo.com

بیاتی و از دست دادن رطوبت محصولات صنایع پخت در قفسه‌های فروشگاه‌ها فرآیندی است که سبب ضرر و زیان بالای تولیدکنندگان می‌گردد. همین امر سبب گردیده است تا محققان به دنبال یافتن راهکارهای عملی در جهت کاهش سرعت بیاتی و به دنبال آن کاهش ضایعات در این دسته از محصولات باشند. بدین منظور در پژوهش حاضر بررسی تأثیر استفاده از مخلوطی از آنزیمی (آنزیم‌های لیپاز، آلفا آمیلاز و زایلاناز) و مخلوطی از امولسیفایرها (امولسیفایرهای داتم، سیترم، سدیم استئاروئیل ۲- لاکتیلات و گلیسرول منو استئارات) در سطوح صفر، ۰/۱، ۰/۲ و ۰/۳ درصد بر خصوصیات کمی و کیفی نمونه‌های دونات تخمیری پرداخته شد. نتایج نشان داد که استفاده از مخلوطی از آنزیم‌ها و امولسیفایرها سبب افزایش میزان رطوبت، حجم مخصوص، تخلخل و کاهش در میزان پارامترهای سفتی بافت (در هر دو بازه زمانی دو ساعت و ۷ روز پس از پخت)، جذب روغن و پراکسید محصول شد. اما از طرفی نتایج نشان داد استفاده از مخلوط حاوی امولسیفایرهای مورد استفاده باعث افزایش میزان مؤلفه L^* و کاهش در میزان مؤلفه a^* پسته می‌گردد، در حالیکه استفاده از مخلوط حاوی آنزیم‌های مورد استفاده باعث کاهش میزان مؤلفه L^* و افزایش در میزان مؤلفه a^* پسته می‌شود. بنابراین می‌توان بیان داشت استفاده همزمان از مخلوط آنزیمی در سطح ۰/۲ درصد و مخلوط امولسیفایری در سطح ۰/۳ درصد منجر به بهبود خصوصیات تکنولوژیکی، حسی و ماندگاری دونات تخمیری می‌شود. از این رو می‌توان گفت با توجه به افزایش تمایل تولیدکنندگان به صادرات این دسته از مواد غذایی و ایجاد ارزش افزوده بالاتر، استفاده از فرمولاسیون ارائه شده، سبب افزایش ماندگاری دونات، این میان وعده پرترفدار، می‌گردد.