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Investigating the Possibility of Increasing the Shelf life of Fermented Doughnut by Edible Cellulose Films

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ABSTRACT

The staleness of bakery products is divided into two categories: crust and crumb staleness, which usually occurs due to moisture transfer from the crumb to the crust. The use of glaze in a product such as fermented doughnuts prevent crust staleness by creating a coating film on the product. Therefore, the purpose of this study was to investigate the effect of using glaze prepared with two hydrocolloids, Carboxymethyl Cellulose (CMC) and Hydroxypropyl Methyl Cellulose (HPMC), at levels of 0, 0.3, and 0.5 % on the characteristics of fermented doughnut. The results showed that the sample containing 0.5 % HPMC had the highest moisture content and the control sample had the lowest. It is important to note that the moisture content of all produced doughnut samples was within the standard allowable range. On the other hand, the lowest and highest oil content were reported in the samples coated with 0.5 % HPMC and the control sample, respectively. By examining the technological properties, it was observed that the use of a 0.5% HPMC increased the specific volume, porosity and brightness of the crust (L* value) and reduced the redness (a* value) and yellowness (b* value) of the doughnut crust, as well as the peroxide value, compared to the sample. By examining the texture and sensory properties during storage, the highest level of softness and sensory acceptance by the consumer was observed in the sample treated with 0.5% HPMC. Therefore, the use of glaze made from cellulose derivatives is recommended as one of the safe and available ingredients to increase the shelf life and improve the technological properties of this widely consumed snack.

1.Introduction

Staling and loss of moisture in bakery products on store shelves is a process that causes high losses for manufacturers. This has led researchers to seek practical solutions to reduce the rate of staling and subsequently reduce waste in this category of products. According to surveys conducted by doughnut production units in Khorasan Razavi province (Nan Razavi factory), the total number of doughnuts produced in the two cities of Mashhad and Tehran during the first six months of 2023 exceeded 30 million, of which about 20% was waste and returned product. It is worth noting that the main reason for this return of goods has been reported to be the loss of softness of the texture and staleness of the final product. Therefore, as mentioned above, it is necessary to conduct further studies in the field of formulation and packaging of this product.

Doughnut has two parts: the fried part (crust) and crumb. The fried part is on the surface, which is in direct contact with the oil. This part has the most moisture removal and the most oil absorption, and ideally has a golden-brown color and a crispy texture. Doughnut crumb is similar to a cake and if it does not receive enough heat during frying, the gelatinization of the starch is delayed. The humidity of this part is higher than the surface, which causes moisture to migrate to the fried part during storage, destroying the crispness of the surface [1].

In the baking industry, coatings and glazing are used to improve the quantitative and qualitative properties of some products. In fact, the use of coatings as a type of coating to increase the shelf life, taste and overall acceptance of products is common. Coatings are specifically used to cover the surfaces of bakery products and provide a transparent appearance to the product and act as a barrier against moisture evaporation from the surface of bakery products with relatively high humidity. Coatings are generally divided into two categories: one is used before baking and the other after baking, which are used on the surface of bakery products. Coatings used before baking are usually made of eggs and water and may also contain various sugars, gums and starches and they used to create properties such as transparency, glossiness, and thin film formation on the surface of bakery products, and they also contribute to creating a brown color on the surface of bakery products.

In this regard, chin *et al*., (2011) investigated the effect of using glazing on the staleness process of bread crust and crumb during storage and observed that the use of corn starch, egg white, and skimmed milk reduced the firmness of the bread crumb and the moisture content of the product crumb decreased by about 1% during a six-day storage period [2]. In the present study, carboxymethyl cellulose (CMC) and hydroxypropyl methyl cellulose (HPMC) were used as glaze. In fact, these compounds are modified cellulose. CMC is a linear, long-chain, water-soluble polysaccharide and the most important natural gum improved by chemical methods.

HPMC is obtained by the reaction of alkaline cellulose with a mixture of methyl chloride and propylene oxide and is one of the compounds that has an excellent film-forming capacity due to its linear structure. This polymer is non-toxic, odorless, tasteless and inexpensive and provides a good barrier against oxygen, carbon dioxide and lipids [3]. On the other hand, methyl cellulose and HPMC are the only gums that form gels when heated and return to their original viscosity when cooled. These properties make these gums suitable for use in fried foods, as they act as a barrier against oil absorption. These compounds slow down the loss of moisture in the product and help maintain the freshness of the product during storage [4]. In this regard, Zolfaghari et al., (2013) investigated the qualitative changes in doughnuts under the

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influence of coating with gums and the use of the fermentation process and stated that the slope of the moisture loss graph of doughnut samples coated with methyl cellulose gum was lower and more uniform than that of samples without coating [5]. Therefore, the purpose of this study was to investigate the effect of using glaze prepared from two gums, CMC and HPM, and to evaluate the characteristics of the manufactured product, and its shelf life was evaluated in order to introduce the best coating 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. The yeast was also purchased from Razavi Yeast Company, CMC and HPMC gums from Petro Pars Novin Company (Tehran), and other materials required for the experiments, including frying oil (Bahar, Tehran), powdered milk, salt, sugar and eggs, were purchased from a confectionery store. All chemicals were also purchased from Merck, Germany.

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. After preparing the dough, it was molded with an outer diameter of 8 cm and an inner diameter of 3 cm and was spread to a thickness of 15 mm. The molded dough was placed in a tray and placed in a hothouse (backcombi model, Miwe, Germany) for 45 mins with 80% relative humidity of and a temperature of 43 °C to complete the fermentation period [6].

Next, glazes prepared with two hydrocolloids, CMC and HPMC, at levels of 0, 0.3, and 0.5 % was applied to the samples by brushing. 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 in order to stabilize and stabilize the oil temperature, the fryer was turned on one hour before the start of frying and the fryer tank was filled with two liters of frying oil. At each frying stage, two pieces of dough were placed in a special stainless-steel basket of the device and fried. After half of the frying time, the basket was removed from the device and 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 [7].

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, numbers 16-44 and 10-30, respectively [8].

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 [8].

[DOI: 10.22034/FSCT.22.163.242]

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 Image J 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 [9]. Next, in order 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 [10].

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 [11] 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 a rank coefficient of 4, 2, 2, and 3, respectively. Each of the doughnut samples was evaluated by 10 judges during three time periods of 2h, 3, and 7 days after baking. The overall acceptance rate of the produced samples was reported using equation 2.

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

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

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 was used. 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

Table 1 shows the effect of using edible coating prepared with two hydrocolloids CMC and HPMC at levels of 0, 0.3 and 0.5% on the moisture content of the produced samples compared to the control sample (without glazing). As can be seen, the sample containing 0.5% HPMC had the highest and the control sample had the lowest moisture content ($P<0.05$). According to the Iranian National Standard No. 16980, the maximum moisture content for doughnut is 23%, which according to Table 1; the moisture content of all produced doughnut samples is within the permissible range of the standard [12].

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Table 1. The effect of edible cellulose films on physicochemical and technological properties of fermented doughnut

Glaze	Moisture (%)	Oil (%)	Specific Volume (ml/g)	Porosity (%)
Blanke	20.10±0.00[c]	23.10±0.53[a]	3.12±0.02[b]	18.42±0.21[c]
0.3% CMC	20.73±0.14[b]	22.72±0.60[ab]	3.51±0.01[ab]	18.92±0.09[bc]
0.5% CMC	21.68±0.47[ab]	22.16±0.48[ab]	3.75±0.03[ab]	19.66±0.10[b]
0.3% HPMC	21.30±0.05[ab]	22.03±0.48[ab]	3.62±0.00[ab]	19.52±0.32[b]
0.5% HPMC	22.17±0.12[a]	21.37±0.48[b]	4.03±0.02[a]	21.17±1.08[a]

(Means with different letters in each column differ significantly in P<0.05)

Moisture is one of the quality characteristics of doughnuts that affects the staleness and shelf life of the product. As observed, the addition of a edible coating containing CMC and HPMC increased the moisture content of the doughnut. In this regard, Wang et al. (2023) stated that compounds such as HPMC and methyl cellulose gelatinize during thermal processes and form a protective layer. This layer prevents the moisture of the product from escaping and the oil from entering during the frying process [13]. On the other hand, Siriwongwilaichat and Kongpanichtrakul (2021) investigated the improvement of the quality of gluten-free doughnuts using three gums: xanthan gum, CMC, and HMC, and stated that the moisture content of the product increases by adding the mentioned gums. Their results showed that HMC gum has a greater ability to maintain and preserve product moisture than CMC [14]. Zolfaghari *et al.,* (2013) also investigated the qualitative changes in doughnuts under the influence of coating with gums and using the fermentation process and stated that the slope of the moisture loss graph of doughnut samples coated with methyl cellulose gum was lower and more uniform than that of samples without coating. They attributed this to the ability of methyl cellulose gum to create a protective layer to prevent moisture from escaping [5]. Also, Maghsoud *et al.,* (2024) investigated the effect of adding CMC and HPMC on the physicochemical, textural and sensory properties of gluten-free pancakes and stated that the addition of these gums increased the moisture content of the product. They attributed this to the ability of the gums used to retain moisture in the product, and they also stated that HPMC wax has a greater ability to retain moisture than CMC [15].

3.2. Oil

Table 1 shows the effect of using edible coating prepared with two hydrocolloids, CMC and HPMC, on the oil content of the produced samples compared to the sample without glazing. As can be seen, the sample containing 0.5% HPMC had the lowest oil content and the control sample had the highest oil content ($P<0.05$). According to the Iranian National Standard No. 16980, the maximum oil content in doughnut is 25%, and by examining the results, it is clear that all samples are within the permissible range in terms of oil content [12].

During the frying process, the moisture in the product evaporates and oil molecules replace water molecules, and therefore, the amount of oil absorbed increases with decreasing humidity [16, 17]. On the other hand, Ananey-Obiri *et al*., (2018) stated that coating before the frying process creates a layer, and the layer acts as a barrier between the food and the frying oil, reducing the size and number of pores on the food surface. Therefore, coating in this way reduces moisture removal and also reduces oil absorption during the frying process. According to the results of the evaluation of the moisture content of the doughnut, it seems that HPMC has a greater ability to reduce the amount of oil absorption by the product during the frying process than CMC because it had a greater effect on increasing the moisture content of the doughnut [16]. In this regard, Wang *et al*., (2023) stated that compounds such as HPMC and methyl cellulose gelatinize during thermal processes and form a protective layer. This layer prevents the product's moisture from escaping and oil from entering during the frying process [13]. Zolfaghari *et al.,* (2013) investigated the qualitative changes in doughnut under the influence of coating with gums and using the fermentation process and stated that the oil absorption rate of doughnut samples coated with methyl cellulose gum was lower than that of samples without coating. They attributed this to the ability of methyl cellulose gum to create a protective layer in preventing oil from entering the doughnut [5]. Sabbaghi (2021) also investigated the use of hydrocolloid compounds (xanthan and CMC) in doughnut formulations with the aim of reducing oil absorption and stated that increasing the amount of the aforementioned gums in the doughnut formulation reduced the oil absorbed by the product. He attributed this to the reduction in the moisture loss of the product [18].

3.3. Specific Volume and Porosity

Table 1 shows the effect of using edible coating prepared with two hydrocolloids, CMC and HPMC, on the specific volume and porosity of the produced samples compared to the sample without glazing. As can be seen, the sample containing 0.5% HPMC had the highest specific volume and porosity, and the control sample had the lowest ($P<0.05$).

The increase in volume in baked goods is influenced by several factors. The amount of air bubbles in the dough (whether physical, chemical, or biological), the expansion of these air cells during the baking process, or the evaporation of water in the dough due to increased temperature are some of these factors [19]. In doughnut formulations, oil is one of the factors that keeps the air bubbles entering the dough during the mixing process. In fact, by creating a protective layer around the air bubbles entering the dough, oil is effective in keeping them in the dough and even preventing them from bursting due to expansion during the baking process [20]. As the results showed, the addition of HPMC had a greater effect on increasing the specific volume of the doughnut than CMC. It seems that using edible coating containing the aforementioned gums makes the product crust more elastic due to its higher humidity. This allows air bubbles to expand further during the frying process, resulting in an increase in product volume. In this regard, Kurek *et al*., (2021) stated that coating products during deep frying improves the porosity and water absorption of the product surface and reduces the penetration of oil into the product [21].

In this regard, Maghsoud *et al*., (2024) also investigated the effect of adding CMC and HPMC on the physicochemical, textural, and sensory properties of gluten-free pancakes and stated that increasing the amount of the aforementioned gums increased the specific volume of the product [15]. On the other hand, Siriwongwilaichat and Kongpanichtrakul (2021) investigated the improvement of gluten-free doughnut quality using three gums: xanthan gum, CMC, and hydroxymethyl cellulose and stated that adding the aforementioned gums increased the specific volume of the product. Their results showed that hydroxymethyl cellulose gum has a greater ability to retain and maintain gas in the product than CMC [14]. On the other hand, Movahhed *et al*., (2017) investigated the effect of HPMC gum on the quality properties of gluten-free baguette bread based on an equal mixture of corn flour and

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potato flour and stated that by increasing the amount of HPMC gum in the product formulation, the specific volume of the product increased. They attributed the increase in volume to the hydrophilic property of the gum used, which was effective in improving dough expansion and retaining carbon dioxide gas [22].

The amount of porosity in the texture is also directly related to the number of gas cells and, more importantly, their uniform distribution in the product texture [23]. Considering the study of the evaluation section of the texture and specific volume of the doughnut, it was expected that the porosity of the product would change significantly with the addition of the above-mentioned compounds, because the amount of porosity of the product is related to the texture [24&25] and its specific volume. On the other hand, Gazmuri and bouchon (2009) stated that the effectiveness of the coating process is described by the structural characteristics of the coatings and the reduction of the porosity of the product shell during frying [26]. In this regard, Maghsoud *et al.,* (2024) also investigated the effect of adding CMC and HPMC on the physicochemical, textural, and sensory properties of gluten-free pancakes, and their results showed that increasing the amount of the aforementioned gums increases the porosity of the product [15]. Also, Sabbaghi (2021) investigated the use of hydrocolloid compounds (xanthan and CMC) in doughnut formulations with the aim of reducing oil absorption and stated that adding CMC gum increased the porosity of the product [18].

3.4. Crust Color

The sample containing 0.5% HPMC had the highest and the control sample had the lowest level of crust brightness value (L*) (P<0.05) (Table 2).

Table 2. The effect of edible cellulose films on crust color values of fermented doughnut

Glaze treatments	Crust color values (-)		
	L*	a*	b*
Blanke	44.73 ± 1.33^{d}	15.02 ± 0.07^{a}	21.44 ± 0.07^{a}
0.3% CMC	46.00 ± 1.72^{c}	13.91 ± 0.04^{ab}	20.51 ± 0.11^{ab}
0.5% CMC	49.06 ± 2.05^{b}	12.23 ± 0.11^{bc}	18.32 ± 0.06^{bc}
0.3% HPMC	48.23 ± 1.02^{b}	13.10 ± 0.14^{b}	18.90 ± 0.21^{b}
0.5% HPMC	53.16 ± 0.36^{a}	11.42 ± 0.22^{c}	16.63 ± 0.14^{c}

(Means with different letters in each column differ significantly in P<0.05)

In the deep-frying process, the Maillard reaction is facilitated at temperatures above 150°C [27]. On the one hand, this reaction develops the color and flavor of food during the thermal process, and on the other hand, it is an essential mechanism in the formation of acrylamide and heterocyclic amines [13]. Regarding the increase in the amount of L* value of the product crust when using HPMC, it seems that using the aforementioned compound causes a slower release of moisture from the surface of the doughnut during the frying process, and as a result, the product has a more uniform surface, which leads to a brighter surface than the product without a glaze. It is also possible that the aforementioned compound, by preventing oil from entering the product, reduces the intensity of the Maillard reaction, and as a result, the color of the crust becomes brighter. Wang *et al*., (2023) stated in this regard that the use of edible coatings based on cellulose or chitosan seems to have an effect on the color parameters of products during deep frying. For example, in the case of chitosan, the amino

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groups of this compound prevent the Maillard reaction and therefore cause a lighter brown color of the product surface [13]. Also, Maghsoud *et al*., (2024) investigated the effect of adding CMC and HPMC on the physicochemical, textural and sensory properties of gluten-free pancakes and stated that the highest amount of L* value was obtained by adding 1% hydroxymethyl cellulose gum [15]. Also, Nateghi and Rezaei (2021) investigated the effect of xanthan gum and CMC on the physicochemical and sensory properties of baguette bread and stated that the sample containing 0.75% CMC gum and 0.75% xanthan gum had the highest amount of L* value. In this regard, they stated that this group of additives, by maintaining moisture and preventing water from escaping during the baking process, reduces changes in the surface of the final product's crust, which can be effective in increasing this color values [28].

On the other hand, by examining the results, it was observed that the sample containing 0.5% HPMC had the lowest and the control sample had the highest levels of a* (redness) and b* (yellowness) values ($P<0.05$). As stated in the section on evaluating the amount of L* value in fermented doughnut, it seems that adding the aforementioned compounds reduces the intensity of the Maillard reaction by preventing oil from entering the product, and as a result, the color of the product crust becomes lighter. Also, in this regard, Al-Asmar *et al.*, (2018) stated that the coating process of products increases the ability to retain moisture and subsequently reduces the intensity of the Maillard reaction [29]. In this regard, researchers stated that in coated and fried foods such as fried Chinese cake batter and doughnut coated with methylcellulose, the amount of a* (redness) and b* values are reduced due to the reduction in the intensity of the Maillard reaction [30&5]. Maghsoud *et al*., (2024) also investigated the effect of adding CMC and HPMC on the physicochemical, textural, and sensory properties of gluten-free pancakes and stated that by adding the aforementioned gums (at levels of 0.5% CMC and 1% HPMC), the amount of a* and b* values of the product decreased [15].

3.5. Peroxide Value

Figure 1 shows the effect of using edible coating prepared with two hydrocolloids, CMC and HPMC, on the peroxide value of the produced samples compared to the sample without coating. As can be seen, the sample containing 0.5% HPMC had the lowest and the control sample had the highest peroxide value. It should be noted that according to the Iranian National Standard No. 16980, the peroxide value for oil extracted from doughnut is a maximum of 3 mEq\kg, which according to the results, the peroxide value of all fermented doughnut samples produced is within the permissible range of the standard [12].

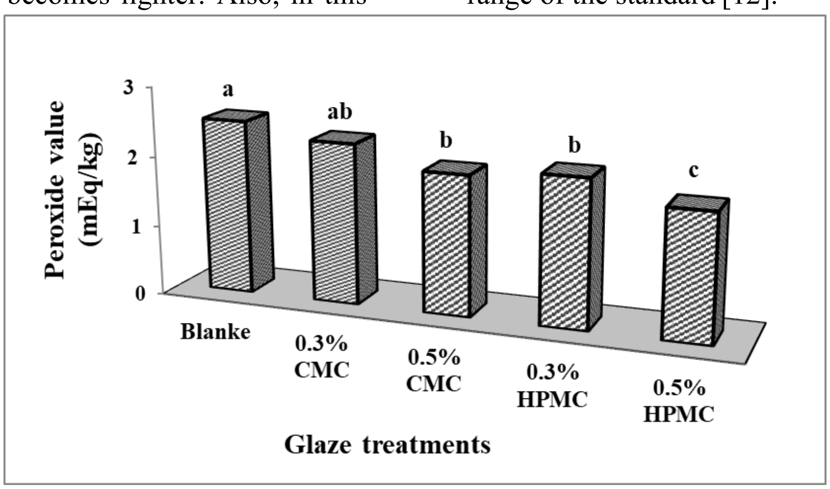

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Fig 1. The effect of edible cellulose films on peroxide value of fermented doughnut (Means with different letters differ significantly in P<0.05)

A peroxide value higher than 6 mEq\kg in a product indicates that the product has become rancid and unusable [31]. Therefore, it is clear that controlling and reducing this parameter is of particular importance. Factors that increase the peroxide value include heat, unsaturation, contamination of the fatty substance with hardened fatty substance, and air. Therefore, according to the results of the moisture and oil absorption evaluation sections in the doughnut, it was expected that the peroxide value would be lower in any sample that absorbed less oil. In this regard, it seems that in the sample containing HPMC, because the oil absorbed by the product is less, and on the other hand, due to the higher moisture content of the product, the temperature of the product core probably increases later, which prevents the increase in the peroxide value. In this regard, Sabbaghi (2021) investigated the use of xanthan and CMC in doughnut formulations with the aim of reducing oil absorption and stated that the presence of a high percentage of oil in the product, due to processes such as flavor reversal and oxidation, causes bad taste of the product and reduces its desirability for consumers [18]. Therefore, efforts to reduce the amount of fat in fried foods are of great importance compared to other quality properties. In general, researchers stated that the role of hydrocolloid compounds in fried foods, in addition to reducing oil absorption, includes maintaining the shape and stability of the product during the process, reducing the loss of solids from the product surface during frying, and improving the organoleptic properties of the product. Also, Paramasivam *et al*., (2022) investigated the effect of gums on the structure, texture, and properties of low-fat banana chips and stated that adding CMC to the product formulation reduced the peroxide value of the product. Regarding the reduction of peroxide value by adding hydrocolloids, these researchers stated that the aforementioned compounds have the ability to inhibit oxygen and therefore reduce this parameter [32]. Ngatirah *et al.,* (2022) also investigated the effect of hydroxypropyl methylcellulose derived from oil palm fruit on the oil absorption rate and physicochemical properties of fried potatoes and stated that gums prevent the transfer of water and oil during the frying process by creating a gel layer [33].

3.6. Firmness of Texture

Figure 2 shows the effect of adding edible coating prepared with two hydrocolloids, CMC and HPMC, at levels of 0, 0.3, and 0.5% on the firmness of the final product during 2h and 3 days after baking fermented doughnuts compared to the control sample (without coating). The sample containing 0.5% HPMC had the lowest and the control sample had the highest tissue firmness in both time periods studied (P<0.05).

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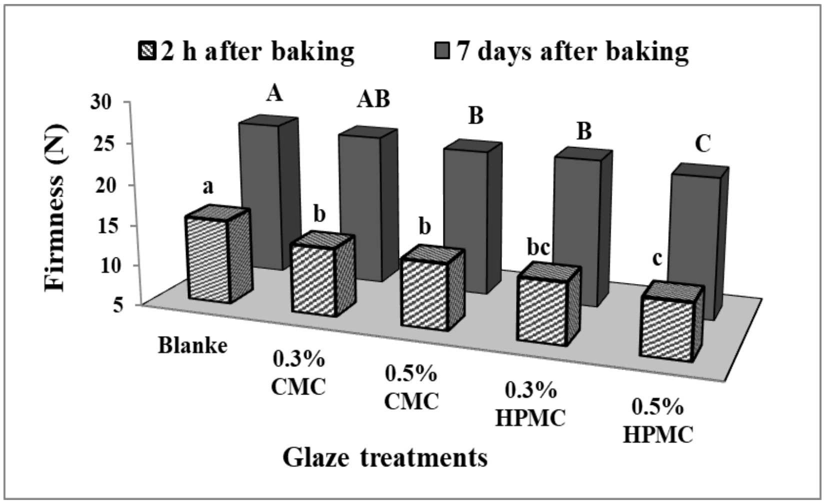

Fig 2. The effect of edible cellulose films on firmness of fermented doughnut during storage (Means with different letters differ significantly in P<0.05)

The occurrence of staleness in bakery products such as bread and fermented doughnuts is related to the moisture content and the amount of water present in the crumb of these products. In such a way that the existence of an inverse relationship between the moisture content of bread and its staleness has been proven. In fact, water can be effective in reducing the firmness of the product's crumb by playing the role of a plasticizer. In addition, considering that the increase in the amount of water available to starch increases the possibility of its crystallization, the significant tendency of moisture-absorbing compounds to absorb water and their high ability to retain water causes less water to be available to starch and, as a result, less starch swells, gelatinizes, and recrystallizes during storage, which ultimately leads to a decrease in firmness and a delay in the product's staleness [34]. In the present study, with regard to the moisture assessment section of fermented doughnut, it was evident that the addition of HPMC had the greatest effect on reducing the firmness of the final product. In this regard, Han *et al.,* (2021) investigated the effect of coating cake dough with methyl cellulose on the firmness of the texture during the frying process and stated that due to the increase in the moisture content of the product, the firmness of the texture also decreased [30]. Also, Maghsoud *et al.,* (2024) investigated the effect of adding CMC and HPMC on the physicochemical, textural, and sensory properties of gluten-free pancakes and stated that the firmness of the product texture decreased with the addition of the aforementioned gums. They attributed this to the ability of the gums used to retain moisture in the product, stating that starch retrogradation and staleness are also delayed due to high moisture levels [15]. Liu *et al.,* (2018) also stated that xanthan gum and HPMC have a softening effect on gluten-free steamed bread [34]. Nateghi and Rezaei (2021) also investigated the effect of xanthan gum and CMC on the physicochemical and sensory properties of baguette bread and stated that the effect of CMC gum in reducing texture firmness was much greater than that of xanthan gum. In this regard, he stated that the reason for the decrease in firmness in bread is the effect of hydrocolloids through their effect on the starch structure, in such a way that hydrocolloids cause changes in the starch structure, which results in a decrease in the distribution and retention of water in starch and the resistance of the bread texture. In other words, they considered the cause of the decrease in firmness in bread

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containing hydrocolloids to be the formation of a complex between the hydrocolloid and the gluten protein, resulting from the reaction between the functional groups present in the hydrocolloid structure with the amino group present in the gluten structure, which increases the consistency and stability of the dough due to the complex formed [28].

3.7. Sensory Evaluation

As the results show (Fig 3), the sample containing 0.5% HPMC had the highest and the control sample had the lowest overall acceptance score in 2h, 3 and 7 days after production (P<0.05).

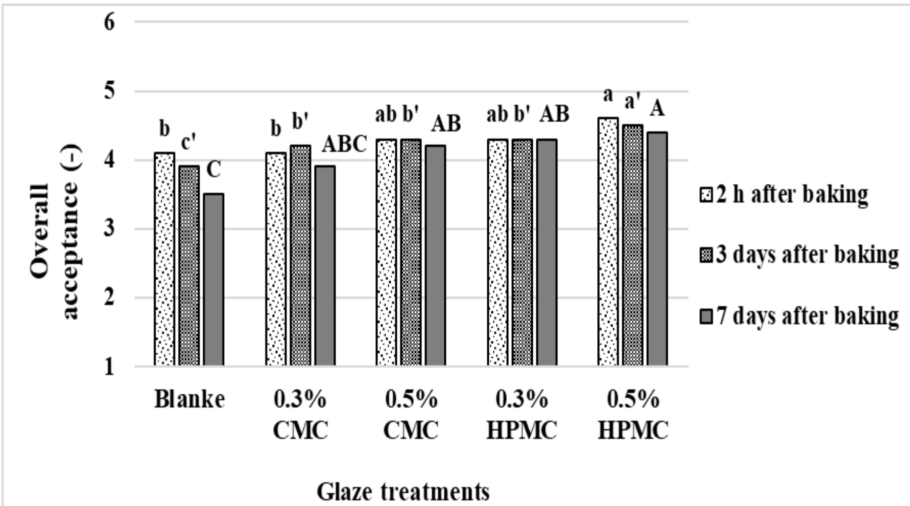

Fig 3. The effect of edible cellulose films on overall acceptance of fermented doughnut during storage
(Means with different letters differ significantly in P<0.05)

In general, researchers stated that the role of hydrocolloid compounds in fried foods, in addition to reducing oil absorption, includes maintaining the shape and stability of the product during the process, reducing the loss of solids from the product surface during frying, and improving the organoleptic properties of the product. Preservation of volatile substances that are suitable for the aroma and flavor of the food, as well as improving the structural properties after processing and preventing fragility and physical damage during storage and transportation of the food are other purposes of using these compounds [18].

As can be seen, the sample containing 0.5% HPMC edible coating had the highest and the control sample had the lowest overall acceptance score in 2h, 3 and 7 days after production (P<0.05), which was expected considering the examination of other sensory parameters evaluated. In this regard, Maghsoud *et al*., (2024) investigated the effect of adding CMC and HPMC on the physicochemical, textural, and sensory properties of gluten-free pancakes and stated that the overall acceptance score of the product increased with increasing the amount of HPMC and CMC [15]. On the other hand, Siriwongwilaichat and Kongpanichtrakul (2021) investigated the improvement of the quality of gluten-free doughnut using three gums: xanthan gum, CMC, and hydroxymethyl cellulose and stated that the overall acceptance score of the product increased with the addition of the aforementioned gums [14].

4. Conclusion

The use of edible coating in bakery and fermented products is one of the easiest methods to increase shelf life and reduce oil absorption in fried products such as fermented doughnut. In the present study, the effect of using edible coating prepared with two hydrocolloids, CMC and HPMC, at levels of 0, 0.3, and 0.5%, on properties of doughnut was examined. Results showed that using edible coating with 0.5% HPMC increased moisture content, specific volume, porosity, crust brightness (L* value), and sensory acceptability, and reduced oil absorption, redness (a* value) and yellowness (b* value) of the doughnut crust, texture firmness, and peroxide value compared to the sample without coating. Therefore, using edible coating is a simple solution can reduce the rate of staleness in this product and prevent its waste.

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بررسی امکان افزایش ماندگاری دونات تخمیری با استفاده از فیلم‌های خوراکی سلولزی

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چکیده

بیاتی محصولات صنایع پخت به دو دسته بیاتی پوسته و مغز محصول تقسیم می‌شود که معمولاً در اثر انتقال رطوبت از مغز به پوسته صورت می‌گیرد. استفاده از رومال‌ها در محصولی نظیر دونات تخمیری به دلیل ایجاد یک فیلم پوششی بر روی محصول از بیاتی پوسته جلوگیری می‌نماید. از این‌رو هدف از انجام این تحقیق بررسی تأثیر استفاده از رومال تهیه شده با دو هیدروکلوئید کربوکسی متیل سلولز و هیدروکسی پروپیل متیل سلولز در سطوح صفر، ۰/۳ و ۰/۵ بر خصوصیات نمونه‌های دونات تخمیری بود. نتایج نشان داد که نمونه حاوی ۰/۵ درصد هیدروکسی پروپیل متیل سلولز از بیشترین و نمونه شاهد از کمترین میزان رطوبت برخوردار بود. ذکر این نکته ضروری است که رطوبت تمامی نمونه‌های دونات تولیدی در محدوده مجاز استاندارد ملی ایران قرار داشتند. از سوی دیگر کمترین و بیشترین میزان روغن به ترتیب در دو نمونه رومال شده با ۰/۵ درصد هیدروکسی پروپیل متیل سلولز و نمونه شاهد گزارش گردید. با بررسی خصوصیات تکنولوژیکی مشاهده شد که استفاده از رومال ۰/۵ درصد هیدروکسی پروپیل متیل سلولز سبب افزایش میزان حجم مخصوص، تخلخل و روشنایی پوسته (مؤلفه *L) و کاهش میزان قرمزی (مؤلفه *a) و زردی (مؤلفه *b) پوسته دونات و همچنین عدد پراکسید در مقایسه با نمونه فاقد رومال شد. ارزیابی بافت و خصوصیات حسی طی مدت زمان نگهداری گویای بیشترین میزان نرمی و مقبولیت حسی نزد مصرف‌کننده در تیمار رومال شده با هیدروکسی پروپیل متیل سلولز به میزان ۰/۵ درصد بود. بنابراین استفاده از رومال تهیه شده از مشتقات سلولز به عنوان یکی از ترکیبات ایمن و در دسترس در افزایش ماندگاری و بهبود خصوصیات تکنولوژیکی این میان وعده پرمصرف توصیه می‌گردد.

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