Journal of Food Science and Technology (Iran)

Homepage: www.fsct.modares.ir

Scientific Research

The investigation of color characteristics and sensory properties of Tafton bread containing demineralized whey powder and transglutaminase enzyme

Sara Saniee[1], Hossein Jooyandeh[2*], Mohammad Hojjati[2], Behrooz Alizadeh Behbehani[3]

1- MSc, Department of Food Science and Technology, Agricultural Sciences and Natural Resources University of Khuzestan, Mollasani, Iran

2- Professor, Department of Food Science and Technology, Agricultural Sciences and Natural Resources University of Khuzestan, Mollasani, Iran

3- Associate Professor, Department of Food Science and Technology, Agricultural Sciences and Natural Resources University of Khuzestan, Mollasani, Iran

ARTICLE INFO

Article History:

Received:2025/10/16

Accepted:2025/11/17

Keywords:

Flat bread,
DWP,
TG,
Lightness,
Taste,
Texture.

DOI: **10.48311/fsct.2026.117075.82895**

*Corresponding Author E-

hosjooy@asnrukh.ac.ir

ABSTRACT

Bread, as a staple food, has an important role in the household consumption basket. In recent years, due to increase in the food cost, bread consumption has increased significantly. Limited resources and the inability to provide sufficient food have led to the nutritional needs of people, especially low-income groups, being met using the simplest methods. One of these methods is the production of breads enriched with compounds such as proteins, salts and vitamins or substances containing them such as whey. However, the use of whey powder, even its demineralized (DWP) form, may lead to a decrease in quality and destruction of the bread texture. Therefore, in this study, transglutaminase (TG) was used to increase protein networks in order to improve the quality of bread. The effect of adding DWP at levels of 0, 4 and 8% and TG at levels of 0, 0.15 and 0.3% on color and sensory characteristics of Tafton bread was investigated. The results showed that with increasing the percentage of DWP and passing the storage time, the brightness (L*) decreased and the redness (a*) and yellowness (b*) increased (P<0.001). Also, with increasing the TG, the brightness (L*) and yellowness (b*) increased and the intensity of redness (a*) decreased (P<0.001). Based on the results of sensory characteristics, from the panelists' perspective, increasing DWP to 4% improved aroma, texture, and color, and increasing TG enzyme to 0.15% improved the texture of bread samples, and therefore this sample was identified as the best formulation for producing Tafton bread.

1- Introduction

Bread is a staple food in many cultures, supplying energy and essential nutrients. It is a major source of carbohydrates, proteins, vitamins, and minerals in numerous countries. For example, in the United Kingdom bread supplies over 10% of daily protein and several micronutrients, although consumption has declined in recent decades [1]. In Norway, bread is also a principal source of energy, dietary fiber, and protein, with average annual consumption around 52 kg per person [2]. Globally, bread is one of the oldest and most widely consumed staples, contributing substantially to nutrition and health [3]. In some countries—such as Iran—flatbread is more popular than wholemeal varieties and is considered a dietary staple [4].

However, bread quality is problematic in many places, particularly Iran, largely because of the low quality of commonly used flour [5]. Wheat flour, the primary ingredient of bread and baked goods, is deficient in the essential amino acid lysine. To address this, researchers have investigated fortification and ingredient substitutions. Adding ingredients rich in lysine—such as whey protein concentrates—can improve the nutritional profile of baked products [6]. Beyond nutrition, studies show that incorporating various forms of whey into bread can enhance physical and sensory qualities [7, 8], improve emulsification and product stability [9], and offer additional benefits such as better taste, extended shelf life, and reduced fat uptake in fried products [10]. For instance, Zhao et al. [11] found that adding different levels of tofu whey powder (TWP) significantly improved the texture of enriched bread versus a control, likely because whey proteins are more hydrophilic [12]. Improvements in aroma and crust color of TWP-enriched bread may also stem from lactose in dried whey powder (DWP), which promotes the Maillard reaction during baking [13].

Bread, as a staple food, plays a vital role in providing energy and nutrients in many cultures. It contributes significantly to the supply of carbohydrates, proteins, vitamins and minerals in many countries. For example, in the United Kingdom, bread provides more than 10% of the daily protein and various micronutrients, although its consumption has decreased in recent decades [1]. In Norway, bread is also a major source of energy, dietary fiber and protein, with an average annual consumption of 52 kg per person [2]. Globally, bread is one of the oldest and most widespread staple foods in diets, making a significant contribution to nutrition and health [3]. In some countries, such as Iran, flatbread is more popular than wholemeal bread and is considered a staple food [4]. However, bread quality in many countries, especially in Iran, has many problems, one of the most important reasons for which is the low quality of flour consumed [5]. Also, wheat flour, the main ingredient used to produce bread and baked goods, is deficient in lysine, an essential amino acid. Therefore, many researchers have focused on improving the quality of baked goods by adding other ingredients. To improve this quality, the use of additives such as whey protein concentrates, which contain high amounts of lysine, can be effective [6]. In addition to nutritional properties, various studies have shown that adding different types of whey to bread and baked goods can improve their physical and sensory properties [7, 8]. In addition, the addition of these proteins to baked goods improves the emulsification capacity and stabilization of the product [9]. In addition to improving physical and sensory properties, the use of whey proteins in bakery products can also have other benefits such as improving taste, increasing shelf life, and reducing fat absorption in fried products [10]. In this regard, Zhao et al. [11], in a study aimed at investigating the effect of different levels of tofu whey powder (TWP) on bread quality, reported a significant improvement in the texture of enriched bread samples compared to the control sample. This improvement was probably due to the greater hydrophilicity of whey proteins [12]. In addition, the improvement in the aroma and color of Tafton bread may also be due to the presence of lactose in the demineralized whey powder (DWP) and, as a result, the enhancement of the Maillard reaction during the baking process [13].

There are many processes in the food industry in which enzymes are used [14]. These processes mainly include improved extraction, bioconversions and synthesis, changes in performance, viscosity reduction and flavor modification [15]. The enzyme transglutaminase, which catalyzes acyltransferase processes, can help improve the texture and quality of bakery products [16]. By creating covalent bonds between proteins, this enzyme creates unique features in the texture of food products, which makes them highly stable against changes in pH and temperature [17]. Various studies have also confirmed the positive effect of this enzyme on the physical and visual properties of bread. For example, Redd et al. [18] reported that the use of this enzyme in breads prepared with gluten-free flour improved the properties of bread compared to control samples. Also, the findings of Moradi et al. [19] in the field of gluten-free Tafton bread showed that the addition of transglutaminase enzyme along with guar gum in the bread formulation led to an increase in brightness and a decrease in the color indices a and b of the product. In another study, Abbaszadeh [20] stated that the combination of ascorbic acid and microbial transglutaminase enzyme in the production of Barbari bread caused a significant increase in the brightness of the bread surface. Similarly, Babakhani et al. [21] also reported similar results; such that the addition of 0.5% of this enzyme increased the overall acceptance of the product, while increasing its concentration beyond this value had a negative effect on the sensory scores of the treatments.

Therefore, considering that it seems that the simultaneous use of whey compounds of DWP and TG enzyme in the formulation of bakery products can be considered as an effective strategy in improving the quality of bread and bakery products, this study was conducted to investigate the effects of the two aforementioned factors on the color and sensory characteristics of Tafton bread

2- Materials and methods

This research was conducted at Agricultural Sciences and Natural Resources University of Khuzestan (Mollasani). Tafton bread samples were produced in the university bakery. Measurement of color parameters (L*, a*, and b*) and evaluation of sensory properties of the produced Tafton bread samples were carried out in the laboratories of the Food Industry Department of Khuzestan University of Agricultural Sciences and Natural Resources.

2-1- Materials

Tafton Lavash flour with an extraction percentage of 83% was obtained from Khuzestan Flour Company (Ahwaz), active dry yeast from Dezful Yeast Company, and demineralized whey powder from Iran Milk Industries Company (Pegah). The composition of demineralized whey powder included 18.4% protein, 68.3% lactose, 6.2% ash, and 0.6% fat. Also, transglutaminase (TG) enzyme was obtained from BDF Natural Additives Company, Spain. The average activity of this enzyme with microbial origin was 100 units per gram of protein. Other chemicals used in this study, such as sodium hydroxide, sulfuric acid, hydrochloric acid, and other reagents, were obtained and used from Merck.

2-2- Bread making procedure

In this study, bread dough was prepared using the method of Ruzegar et al. (2015) with slight modifications [22]. For every 100 kg of flour, 2% salt and 1% yeast were used. Demineralized whey powder at levels of 0, 4 and 8% and transglutaminase enzyme at levels of 0, 0.15 and 0.30% (w/w) were added to the flour mixture. The dough preparation steps included mixing the ingredients, kneading, primary fermentation, kneading, intermediate fermentation, shaping and baking the bread at 300°C. The physicochemical properties of the breads were measured immediately after production.

2-3- Color evaluation

Bread crust color was evaluated using a colorimeter (Konica Minolta, model 400-CR, made in Japan). To calibrate the instrument to measure the color of the samples, a white standard plate (L*=43.94, a*=0.39, and b*=1.80) was used. After calibrating the instrument, bread samples with specific dimensions (10×10 cm) from the middle and peripheral parts of the bread were placed on the glass part of the instrument in 3 replicates. Then, color parameters including L* index (sample transparency, with a scale of 0 = black and 100 = white), a* index (positive values indicating sample redness, and negative values indicating sample greenness) and b* index (positive values indicating sample yellowness, and negative values indicating sample blueness) were measured by a colorimeter at two time intervals immediately after bread making and 72 hours later [23].

2-4- Sensory evaluation

The sensory characteristics of Tafton bread, including aroma, flavor, color, and texture, were evaluated by 20 evaluators using a hedonic method, immediately after baking and after 72 hours of storage at 25°C in polyethylene bags. Scoring was based on a scale of 1-9 (where 1 is the lowest and 9 is the highest score) [7].

2-5- Data Analysis

Considering the two variables DWP at 3 levels of 0, 4 and 8% and TG enzyme at 3 levels of 0, 0.15 and 0.30%, 9 treatments were produced and the effect of the mentioned variables on the sensory properties and color of Tafton bread was investigated during 3 days of storage. The mean data (3 replications) were analyzed using a factorial design in a completely randomized format and with SPSS software (version 24). Analysis of variance (ANOVA) and Duncan's test were used to compare the means (significance level $P< 0.05$).

3- Results and discussion

3-1- Color assessment

Color is considered an important criterion for the initial acceptance of baked products by consumers. In general, the color of bread crust is caused by Maillard reactions (reactions between reducing sugars and amino compounds). Some of the color of bread crust is also related to the caramelization of sugars. Caramelization of sugars can occur even in the absence of Maillard reactions, especially when baking temperatures are higher than 155 °C. Since enzymatic activities are temperature-sensitive, any change in dough temperature or delay in baking may affect the color of bread crust [24]. In addition, the color of the surface of the product depends on the physicochemical properties of the dough and the baking conditions [25].

The results of the analysis of variance for the color parameters L*, a*, b* in the Hunter Lab color system are shown in Table (1). According to this Table, all three variables demineralized whey powder, enzyme treatment, and storage time had a significant effect on the color parameters ($P<0.001$); but no significant interaction between the tested variables was observed on the color parameters L*, a*, b* ($P> 0.05$).

Table 1. Analysis of Variance for the Effect of Transglutaminase Enzyme (TG) and Demineralized Whey Powder (DWP) on Colorimetric Parameters

Source of Variation	Degrees of Freedom	Mean Squares (MS)		
		L*	a*	b*
DWP	2	26.12***	7.53***	37.64***
TG	2	169.00***	1.17***	24.39***
Day	1	221.35***	1.75***	84.40***
DWP × TG	4	0.22 ns	0.02 ns	0.15 ns
DWP × Day	2	2.53 ns	0.03 ns	0.80 ns
TG × Day	2	0.84 ns	0.02 ns	0.05 ns
Demineralized Whey Powder × Enzyme × Day	4	1.08 ns	0.03 ns	0.12 ns
Error	36	7.16	0.05	0.61

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

3-1-1- Effect of DWP on color parameters

The effect of different amounts of demineralized whey powder on the L* parameter (brightness) is shown in Table (2). According to this Table, with increasing percentage of DWP, the amount of L* of bread samples decreased significantly compared to the control sample (Table 2). Azarbad [26] reported that adding whey powder to bread causes its color to become darker and the decrease in L* value is due to the Maillard reaction. The addition of dairy proteins such as DWP, depending on the amount used, causes the bread crust to darken. This color change is due to the Maillard browning reaction, which is a chemical reaction between amino groups and reducing sugars. In the case of milk derivatives subjected to high temperatures, lactose as a reducing sugar combines with the amino acid lysine and leads to the formation of brown melanoidins. These results were similar to those of Krupa-kozak et al. [27]. Also, Sahraiyan et al. [28] stated that adding more than 3% cheese powder reduces the amount of L* value in the crust.

Table (2) shows that with increasing DWP percentage, the amount of a* value in bread samples increased significantly (P<0.001). In other words, the intensity of redness of the samples increased significantly compared to the control sample. The increase in redness of the bread crust, which makes it darker, is due to the increase in the occurrence of non-enzymatic browning reaction. The results of this study are consistent with the results of Zhou et al. [29] in investigating the effect of whey and soy protein on bread.

As shown in Table (1), the variable of demineralized whey powder had a significant effect on the b* parameter (P<0.001). The trend of changes in this parameter is shown in Table (2). According to this Table, with increasing DWP percentage, the amount of b* value (yellowness) of bread samples increased. The results of this study were consistent with the results of Zhou et al. [29] on the effect of whey and soy protein on bread and Mohtarami et al. [30] on improving the physical and rheological properties of bread dough using transglutaminase and asparaginase enzymes and whey powder and inulin. Also, Shin et al. [31] reported that with increasing whey protein levels in gluten-free rice bread, the amount of b* value increases.

Table 2. Main Effect of Demineralized Whey Powder (DWP) on L*, a* and b* Parameter

Demineralized Whey Powder (%)	L*	a*	b*
0	65.99[a]	1.22[c]	13.82[c]
4	63.82[b]	2.14[b]	15.19[b]
8	60.72[c]	2.47[a]	16.71[c]

Means followed by different letters within a column are significantly different at P < 0.05 according to Duncan's multiple range test

3-1-2- Effect of TG on color parameters

According to Table (1), the transglutaminase enzyme variable had a significant effect on the color parameters L*, a* and b* (P<0.001). Table (3) shows the effect of different percentages of the enzyme on the brightness of the bread samples. As can be seen, with increasing percentage of the enzyme, the brightness of the samples increased compared to the control sample. This change can be attributed to the reduction of Maillard browning reactions, which is caused by the action of the transglutaminase enzyme. This enzyme reduces the amount of available lysine by creating cross-links between the amino acids lysine and glutamine, and consequently reduces the Maillard reaction [32]. These links can also affect the physical structure of the bread and change its color [33]. These results are consistent with the findings of Moradi et al. [19] regarding the addition of transglutaminase enzyme, guar gum and sodium caseinate to gluten-free Tafton bread based on potato powder. Also, similar results were observed in the study of Pourmohammadi et al. [34] in the study of adding transglutaminase enzyme to wheat bread containing barley flour without a coating. Abbaszadeh [20] also reported in his study on adding ascorbic acid and microbial transglutaminase enzyme to Barbari bread that the brightness of the bread samples increased with increasing the percentage of TG enzyme.

Table (3) shows the effect of different enzyme concentrations on the redness (a*) of bread samples. As enzyme percentage increased, a* decreased — i.e., samples became less red than the control. This trend mirrors the L* results: reduced non-enzymatic browning leads to lower redness and a lighter crust color. These findings agree with Abbaszadeh [20], who examined the effects of ascorbic acid and microbial transglutaminase on Barbari bread quality.

According to Table (3), with increasing enzyme percentage, the yellowness (b^*) of the bread samples increased. Transglutaminase enzyme increases yellowness by forming a complex with xanthophyll (yellow pigment in dough) or protecting the hydroxyl groups of the pigment from oxidation. These results are consistent with the findings of Fazeli et al. [35] in investigating the effect of xanthan, guar gums and transglutaminase enzyme on the physicochemical and textural properties of gluten-free donuts.

Table 3. Main Effect of Transglutaminase Enzyme (TG) on L*, a* and b* Parameter

TG (%)	L*	a*	b*
0	60.63[c]	2.19[a]	14.12[c]
0.15	63.18[b]	1.95[b]	15.16[b]
0.30	66.73[a]	1.68[c]	16.45[c]

Means followed by different letters within a column are significantly different at P< 0.05 according to Duncan's multiple range test

3-1-3- Effect of storage on color parameters

As shown in Table (1), storage time significantly affected all color parameters (P< 0.001), causing a decrease in brightness and increases in redness and yellowness. According to Table (4), brightness decreased over the three-day storage period. Nosrati et al. [36] similarly reported that storage time significantly reduced brightness in cheese when ultrafiltrated whey powder and lactose were added. Table (4) also shows that a* (redness) increased by day 3, indicating greater redness compared with the control. Likewise, yellowness increased over time, with the highest b* observed on the third day of storage.

Table 4. Main Effect of Storage Time on L*, a* and b* Parameter

Storage Duration (day)	L*	a*	b*
1	65.54^{a}	1.76^{b}	13.99^{b}
3	61.49^{b}	2.12^{a}	16.49^{a}

Means followed by different letters within a column are significantly different at P< 0.05 according to Duncan's multiple range test

3-2- Sensory results

In this study, sensory evaluation of bread samples was performed including color, flavor, aroma, and texture characteristics. Table (5) shows the results of variance analysis of sensory evaluation data of produced bread samples. According to this Table, the variable demineralized whey powder (DWP) had a significant effect on color, aroma, and texture characteristics, while transglutaminase enzyme (TG) had a significant effect only on texture. The effect of storage time was also significant on all sensory characteristics. Among the interaction effects, the effect of demineralized whey powder × day on color, aroma, and flavor, and the effect of enzyme × day on texture were significant.

Table 5. Analysis of Variance for the Effect of Transglutaminase Enzyme (TG) and Demineralized Whey Powder (DWP) on Sensory Evaluation Parameters

Source of Variation	Degrees of Freedom	Color	Aroma	Taste	Texture
DWP	2	4.08***	1.40***	0.40^{ns}	4.19***
TG	2	0.00^{ns}	0.0.3^{ns}	0.06^{ns}	3.07***
Day	1	9.77***	17.71***	20.03***	16.88***
DWP × TG	4	0.03^{ns}	0.02^{ns}	0.02^{ns}	0.03^{ns}
DWP × Day	2	0.13*	1.74***	2.72***	0.02^{ns}
TG × Day	2	0.38^{ns}	0.61^{ns}	0.49^{ns}	16.98***
DWP × TG × Day	4	0.01^{ns}	0.06^{ns}	0.02^{ns}	0.03^{ns}
Error	18	0.03	0.10	0.17	0.06

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

3-2-1- Effect of DWP

As mentioned above, the variable of demineralized whey powder had a significant effect on the color, aroma and texture of bread samples (P<0.001), but did not affect the taste (P>0.05). The effect of different amounts of demineralized whey powder on the taste quality of breads is shown in Table (6). Adding 4% DWP slightly increased the taste score of bread samples, but using a higher amount of DWP (8%) decreased the taste score. However, as mentioned, these changes were not significant (P>0.05). In accordance with the results of this study, Haratian et al. [37] stated in their study that adding 7.5% whey did not have a significant effect on the taste of bread. Also, Jamalian and Rahimi [38] reported in similar results that adding 1 to 5% whey powder did not change the taste of Sangak bread samples.

According to Table (5), the effect of DWP on the aroma characteristic was significant (P<0.001). According to Table (6), with increasing DWP values, the aroma characteristic score of breads increased compared to the control sample, and 4 and 8 percent DWP values had the same effect on the aroma characteristic score, which was in accordance with the research of Jooyandeh et al. [7], who showed that the organoleptic properties of bread improved with increasing whey content. Table (6) shows the effect of different DWP values on the color and texture scores of bread samples, respectively. As can be seen in this Table, with increasing DWP percentage, the color score of the samples increased significantly (P<0.001), which was consistent with the results of Morad khani et al. [39]. Also, sensory evaluation of texture showed that with increasing DWP percentage, the score of this characteristic increased significantly (P<0.001). In accordance with the results of this study, Zhao et al. [29] reported an improvement in the texture score of the samples compared to the control sample in their study of the effect of tofu whey powder (TWP) at different levels. The texture desirability can be attributed to the greater hydrophilicity of whey proteins. The reason for the improvement in the aroma and color of the Tafton bread samples as a result of the addition of whey could be due to the lactose present in DWP and the development of the Maillard reaction. In accordance with the results of this study, Haratian et al. [37] showed that with increasing the percentage of whey powder, the sensory score increased compared to the control sample. Also, Jooyandeh and Minhas [40], in their study of the properties of loaf bread enriched with fermented whey protein concentrate (FWPC) and whey protein concentrate (WP), stated that by replacing 50% of the water used in dough preparation with WP or 25% of the water with FWPC, loaf bread with a soft and flexible texture and appropriate baking quality can be produced.

Table 6. Main effects of demineralized whey powder (DWP) on sensory properties

DWP (%)	Taste	Aroma	Color	Texture
0	7.84^{a}	6.91^{b}	7.83^{b}	7.59^{b}
4	8.12^{a}	7.25^{a}	8.07^{a}	8.04^{a}
8	7.96^{a}	7.47^{a}	7.93^{ab}	7.95^{a}

Means followed by different letters within a column are significantly different at P< 0.05 according to Duncan's multiple range test

3-2-2- Effect of TG

Transglutaminase is the only commercial enzyme used to form covalent bonds between food proteins [41]. To date, extensive studies have investigated the possibility of using TG enzymes to improve the properties of various food products such as meat products [42], fish products [43], baked goods [16], edible films [44, 45], and dairy products [46-50].

The results of this study showed that the transglutaminase (TG) enzyme variable had a significant effect on the texture characteristics of bread samples (P<0.001), but had no effect on the color, aroma, and flavor characteristics (P>0.05). Also, according to Table (5), the interaction effect of demineralized whey powder (DWP) × transglutaminase (TG) enzyme on all sensory characteristics of bread samples was not significant (P>0.05). The effect of different amounts of enzyme on the taste, aroma, and color scores of bread samples is shown in Table (7). According to this Table, increasing enzyme levels in bread samples caused a significant difference (P<0.05) in the texture score compared to the control sample, which was similar to the results of Abbaszadeh et al. [20] and Azarbad et al. [26]. Also, in similar results, Collar et al. [51] determined a significant improvement in bread texture as a result of TG enzymatic treatment; however, these researchers also reported improvements in other sensory characteristics of the product, especially aroma, contrary to the results of the present study.

Table 7. Main effects of transglutaminase (TG) enzyme on sensory properties

TG (%)	Taste	Aroma	Color	Texture
0	7.99^{a}	7.25^{a}	7.88^{a}	7.82^{b}
0.15	7.93^{a}	7.23^{a}	7.98^{a}	7.99^{a}
0.30	8.00^{a}	7.14^{a}	7.97^{a}	7.83^{b}

Means followed by different letters within a column are significantly different at P< 0.05 according to Duncan's multiple range test.

According to Table 7, by adding 0.15% enzyme, the texture quality of the samples increased compared to the control sample, but by increasing the enzyme level to 0.30%, the texture score decreased and the sample texture became firmer. The reason for this phenomenon can be attributed to the creation of more intense and stronger crosslinks between proteins [23]. Also, the trend of changes in the results of the investigation of the physicochemical and sensory properties of cake enriched with fish protein powder and transglutaminase enzyme by Babakhani et al. [21] was consistent with the trend of the results of this study. They stated that with an increase in the transglutaminase enzyme at a level of 0.5%, the overall acceptance increased; but an increase greater than this amount caused a decrease in the sensory score in the treatments.

3-2-3- Effect of storage time

The results of data analysis showed that with the passage of storage time, all sensory scores of bread samples decreased. The initial values of the average color, aroma, taste and texture scores of 8.35, 7.43, 8.50 and 8.26 of the samples were recorded on the first day, which decreased to 7.54, 6.98, 7.45 and 7.47 after 3 days of storage. The decrease in sensory properties of bread and other foods during storage has also been reported by other researchers [6, 16, 50].

4- Conclusion

This study examined the effects of microbial transglutaminase (TG) combined with demineralized whey powder (DWP) on Tafton bread color and sensory quality. TG was used to improve texture by cross-linking dough proteins (whey and gluten), enhancing dough elasticity, gas retention, and chewiness. DWP supplied soluble proteins, salts, and lactose, promoting Maillard reactions and improving crust color and aroma.

Colorimetry results showed that increasing DWP—and storage time—reduced brightness (L*) while increasing redness (a*) and yellowness (b*). Increasing TG raised L* and b* but lowered a*. Sensory panelists reported that higher DWP levels improved aroma, texture, and color.

Increasing TG to 0.15% enhanced only texture and did not affect other sensory attributes. Overall, the combination of 4–8% DWP with 0.15% TG produced Tafton bread with improved nutritional and sensory qualities.

5- Acknowledgment

This research is part of the results of a master's thesis and was conducted with financial support from Khuzestan University of Agriculture and Natural Resources. The authors express their gratitude to the university officials for their support.

6-References

[1] O'Connor, A. (2012). An overview of the role of bread in the UK diet. *Nutrition Bulletin,* 37(3), 193–212.

[2] Svanes, E., Oestergaard, S., and Hanssen, O.J. (2018). Effects of packaging and food waste prevention by consumers on the environmental impact of production and consumption of bread in Norway. *Sustainability,* 11(1), 43–59.

[3] Ribet, L., Kassis, A., Jacquier, E., Monnet, C., Durand-Dubief, M., and Bosco, N. (2024). The nutritional contribution and relationship with health of bread consumption: A narrative review. *Critical Reviews in Food Science and Nutrition*, 1–28.

[4] Jooyandeh, H. (2009). Evaluation of Physical and Sensory Properties of Iranian Lavash Flat Bread Supplemented with Precipitated Whey Protein (PWP). *African Journal of Food Science*, 3(2), 028 -034.

[5] Ter-Sarkissian, N., Zar, M., Ghavifekr, H., Fergueson, T., and Hedayat, H. (1974). High phytic acid in Iranian breads. *Journal of the American Dietetic Association,* 65(6), 651–653.

[6] Nasehi, B., Jooyandeh, H., and Nasehi, R. (2011). Quality Attributes of Soy-pasta During Storage Period. *Pakistan Journal of Nutrition*, 10(4), 307-312.

[7] Jooyandeh, H., Minhas, K.S., and 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.

[8] Jooyandeh, H., and Minhas, K.S. (2009). Effect of Addition of Fermented Whey Protein Concentrate on Cheese Yield and Fat and Protein Recoveries of Feta Cheese. *Journal of Food Science and Technology*, 46(3), 221-224.

[9] Soares, J. P., et al. (2018). Efeito da adição de proteína do soro do leite como substituto do trigo na formulação de bolos sem adição de açúcar. *Brazilian Journal of Food Technology,* 21, e2016190.

[10] Paul, S., Kulkarni, S., Chauhan, R. (2022). Utilization of whey in bakery products—A review. *Indian Journal of Dairy Science,* 75, 297–305.

[11] Zhao, C., Lu, J., and Ameer, K. (2021). Effects of tofu whey powder on the quality attributes, isoflavones composition and antioxidant activity of wheat flour pan bread. *LWT - Food Science and Technology,* 143, 111166.

[12] Alimoradi, F., Hojati, E., Jooyandeh, H., Zehni-Moghadam, S.A.H. and Moludi, J. (2016). Whey proteins: Health benefits and food applications. *Journal of International Research in Medical and Pharmaceutical Sciences*, 9(2), 63-73.

[13] Nooshkam, M., Babazadeh A., and Jooyandeh, H. (2018). Lactulose: Properties, techno-functional food applications, and food grade delivery system. *Trends in Food Science & Technology*, 80, 23-34.

[14] Jooyandeh, H., Aberumand A. and Nasehi B. (2011). Application of Lactoperoxidase System in Fish and Food Products: A Review. *American-Eurasian Journal of Agricultural & Environmental Sciences*, 10(1), 89-96.

[15] Jooyandeh, H., Kaur A. and Minhas K.S. (2009). Lipases in Dairy Industry. *Journal of Food Science and Technology*, 46(3), 181-189.

[16] Saeidi, Z., Nasehi, B., and 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.

[17] Yokoyama, K., Nio, N., and Kikuchi, Y. (2004). Properties and applications of microbial transglutaminase. *Applied Microbiology and Biotechnology,* 64(4), 447–454.

[18] Redd, A.J., Pike, O.A., and Ahlborn, G.J. (2024). Effects of microbial transglutaminase on gluten-free sourdough bread structure and loaf characteristics. *Journal of Cereal Science*, 115, 103833.

[19] Moradi, M., Bolandi, M., Karimi, M., Nahidi, F., and Baghaei, H. (2021). Effect of microbial transglutaminase, guar gum, sodium caseinate additive on gluten-free Taftoon (Based on Potato Powder Variety Agria). *Iranian Journal of Food Science and Technology,* 18(116), 347–356. (In Persian)

[20] Abbaszadeh, M. (2017). Investigation of the effects of ascorbic acid and transglutaminase enzyme on rheological properties of dough and quality attributes of obtained Barbari bread. Master's thesis, Islamic Azad University, Safadasht Branch. (In Persian)

[21] Babakhani, S., Moghaddaszadeh-Ahrabi, S., and Gharakhani, M. (2019). Physicochemical and sensory properties of cake enriched with fish protein powder (FPP) and transglutaminase enzyme. *Journal of Food Science and Technology* (Iran), 16(95), 179–196. (In Persian)

[22] Ruzegar, M.H., Shahedi, M., and Hamdami, N. (2015). Production and rheological and sensory evaluation of Taftoon bread containing flaxseed. *Journal of Food Science and Technology* (Iran), 12(48), 231–244. (In Persian)

[23] Asgharipour, S., Noshad, M., Nasehi, B., Jooyandeh, H., and Beiraghi-Toosi, Sh. (2018). Optimization of physicochemical and functional properties of corn-based snacks containing date kernel flour. *Journal of Food processing and preservation*, 42(3), e13821, 1-8

[24] Kadivar, M. (2008). *Troubleshooting guide for bakery products* (Translation). Isfahan University of Technology Press. (In Persian)

[25] Zanoni, B., Peri, C., and Bruno, D. (1995). Modelling of browning kinetics of bread crust during baking. *LWT - Food Science and Technology,* 28(6), 604–609.

[26] Azarbad, H.R. (2018). Application of transglutaminase enzyme and milk protein concentrate in gluten-free bread premix formulation (for celiac patients) and determination of its chemical, sensory and mechanical texture. Master's thesis, Ferdowsi University of Mashhad. (In Persian)

[27] Krupa-Kozak, U., Bączek, N., and Rosell, C.M. (2013). Application of dairy proteins as technological and nutritional improvers of calcium-supplemented gluten-free bread. *Nutrients, 5*(11), 4503- 4520.

[28] Sahraiyan, B., Habibi Najafi, M.B., Karimi, M., and Haddad Khodaparast, M.H. (2013). Investigating the effect of whey powder on the quantitative and qualitative properties of gluten-free sorghum bread. In *21st National Congress of Food Science and Technology*, 29 October 2013, Shiraz University. (In Persian)

[29] Zhou, J., Liu, J., and Tang, X. (2018). Effects of whey and soy protein addition on bread rheological property of wheat flour. *Journal of Texture Studies,* 49(1), 38–46.

[30] Mohtarami, F., Esmaiili, M., Alizadeh, M., and Ardabili, S. S. (2015). Improvement of

the rheological properties of dough using transglutaminase and asparaginase enzymes, whey powder and inulin. *Iranian Food Science and Technology Research Journal,* 11(4), 445–457. (In Persian)

[31] Shin, M., Gang, D.O., and Song, J.Y. (2010). Effect of protein and transglutaminase on the preparation of gluten-free rice bread. *Food Science and Biotechnology,* 19(4), 951–956.

[32] Aalami, M., and Leelavathi, K. (2018). Effect of microbial transglutaminase on spaghetti quality. *Journal of Food Science,* 12(5), 213–216.

[33] Gerrard, J.A., Fayle, S.E., Wilson, A.J., Newberry, M.P., Ross, M., and Kavale, S. (1998). Dough properties and crumb strength of white pan bread as affected by microbial transglutaminase. *Journal of Food Science,* 62(2), 413–415.

[34] Pourmohammadi, K., Aalami, M., Shahedi, M., and Sadeghi Mahoonak, A. (2011). Effect of microbial transglutaminase on dough rheological properties of wheat flour supplemented with hull-less barley flour. *Journal of Food Science and Technology,* 21(3), 269–279.

[35] Fazeli, A., Mazaheri Tehrani, M., Karimi, M., Sadeghian, A., and Koochaki, A. (2019). The effect of xanthan, guar and transglutaminase on the physicochemical and textural properties of gluten-free doughnut. *Journal of Research and Innovation in Food Science and Technology,* 8(1), 1–14. (In Persian)

[36] Nosrati, G., Jooyandeh, H., Hojjati, M., and Noshad, M. (2023). Impact of ultrafiltrated whey powder and lactulose on survival of *Bifidobacterium bifidum* and color and sensory characteristics of ultrafiltrated synbiotic cheese. *Journal of Food Science and Technology* (Iran), 20(141), 238–249. (In Persian)

[37] Haratian, P., Seyedin, A. S., and Ghazizadeh, M. (2006). An investigation of the effect of whey powder on the quality of hamburger bread. *Journal of Food Science and Technology,* 3(8), 75–82.

[38] Jamalian, J., and Rahimi, A. (2003). Effect of whey powder on rheological properties of dough and staling of Sangak bread. *JWSS - Isfahan University of Technology,* 7(1), 179–190.

[39] Morad Khani, F., Salehi Far, M., and Hashemi, M. (2017). Survey on the effect of Sodium Stearoyel 2-Lactilat emulsifier and whey protein concentrate for improving quality of dough and frozen dough structure. J*ournal of Food Science and Technology* (Iran), 13(59), 11-23. (In Persian)

[40] Jooyandeh, H., and 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.

[41] Jooyandeh, H., and Mortazavi, A. (2019). Impact of addition of milk powder and microbial transglutaminase (TG) on the sensory and textural properties of set yoghurt. *Electronic Journal of Food Processing and Preservation,* 10(2), 121–136.

[42] Trespalacios, P., and Pla, R. (2007). Simultaneous application of transglutaminase and high pressure to improve functional properties of chicken meat gels. *Food Chemistry*, 100, 264–272.

[43] Jongjareonrak, A., Benjakul, S., Visessanguan, W., and Tanaka, M. 2006. Skin gelatin from bigeye snapper and brown stripe red snapper: Chemical compositions and effect of microbial transglutaminase on gel properties. *Food Hydrocolloids*, 20, 1216–1222.

[44] Kouravand, F., Jooyandeh, H., Barzegar, H. and Hojjati, M. (2018). Characterization of cross-linked whey protein isolate-based films containing *Satureja khuzistanica* Jamzad essential oil. *Journal of Food processing and preservation*, 42(3), e13557: 1-10.

[45] Kouravand, F., Jooyandeh, H., Barzegar, H., and 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.

[46] Danesh, E., Goudarzi, M., and Jooyandeh, H. (2017). Effect of whey protein addition and transglutaminase treatment on the physical and sensory properties of reduced-fat ice cream. *Journal of Dairy Science*, 100, 5206–5211.

[47] Torabi, F., Jooyandeh, H., and Noshad, M. (2021). Evaluation of physicochemical, rheological, microstructural, and microbial characteristics of synbiotic ultrafiltrated white cheese treated with transglutaminase. *Journal of Food Processing and Preservation*, 45, e15572, 1-11.

[48] Habibi, S.A., & Jooyandeh, H. (2024). Investigation on the Effect of Persian Gum and Transglutaminase Enzyme on Some Physicochemical and Microstructural Characteristics of Low-Fat Ultrafiltrated Iranian White Cheese. *Food Science & Nutrition*, 12(11), 9810-9821.

[49] Beirami F., Hojjati M. and Jooyandeh H. (2021). The effect of microbial transglutaminase enzyme and Persian gum on the characteristics of traditional kefir drink. *International Dairy Journal*, 112, 1-13 (104843).

[50] Jooyandeh, H., Mortazavi, S.A., Farhang, P., and Samavati, V. (2015). Physicochemical Properties of Set-Style Yoghurt as Effect by Microbial Transglutaminase and Milk Solids Contents. *Journal of Applied Environmental and Biological Sciences*, 4(11S), 59-67.

[51] Collar, C., Bollaín, C., and Angioloni, A. (2005). Significance of microbial transglutaminase on the sensory, mechanical and crumb grain pattern of enzyme supplemented fresh pan breads. *Journal of Food Engineering*, 70(4), 479-488.

مجله علوم و صنایع غذایی ایران

سایت مجله: www.fsct.modares.ac.ir

مقاله علمی_پژوهشی

بررسی ویژگی‌های رنگ و خواص حسی نان تافتون حاوی پودر آب‌پنیر املاح‌گیری شده و آنزیم ترانس‌گلوتامیناز

سارا صنیعی[1]، حسین جوینده[2]*، محمد حجتی[2]، بهروز علیزاده بهبهانی[3]

۱- فارغ‌التحصیل کارشناسی ارشد، گروه علوم و مهندسی صنایع غذایی، دانشکده علوم دامی و صنایع غذایی، دانشگاه علوم کشاورزی و منابع طبیعی خوزستان

۲- استاد گروه علوم و مهندسی صنایع غذایی، دانشکده علوم دامی و صنایع غذایی، دانشگاه علوم کشاورزی و منابع طبیعی خوزستان

۳- دانشیار گروه علوم و مهندسی صنایع غذایی، دانشکده علوم دامی و صنایع غذایی، دانشگاه علوم کشاورزی و منابع طبیعی خوزستان

اطلاعات مقاله

تاریخ های مقاله :

تاریخ دریافت: ۱۴۰۴/۷/۲۴

تاریخ پذیرش: ۱۴۰۴/۸/۲۶

کلمات کلیدی:

نان مسطح،

DWP،

TG،

روشنایی،

طعم،

بافت

DOI:10.48311/fsct.2026.117075.82895

* مسئول مکاتبات:

hosjooy@asnrukh.ac.ir

چکیده

نان به عنوان غذای اساسی سهم مهمی در سبد مصرفی خانوارها دارد. در چند سال اخیر، به دلیل افزایش هزینه مواد غذایی، مصرف نان افزایش قابل توجهی داشته است. محدودیت منابع و عدم امکان تأمین مواد غذایی کافی سبب شده است که نیازهای تغذیه‌ای مردم به ویژه اقشار کم‌درآمد با استفاده از ساده‌ترین روش‌ها تأمین شود. یکی از این روش‌ها، تولید نان‌های غنی شده با ترکیباتی مانند پروتئین‌ها، املاح و ویتامین‌ها یا مواد حاوی آن‌ها نظیر آب‌پنیر می‌باشد. درهرحال استفاده از پودر آب‌پنیر حتی نوع دمینرال آن (DWP) ممکن است منجر به کاهش کیفیت و گسستگی بافت نان شود. به همین دلیل در این تحقیق از تیمار آنزیمی ترانس‌گلوتامیناز (TG) جهت افزایش اتصالات پروتئینی استفاده گردید تا از این طریق بتوان کیفیت نان را بهبود بخشید. در این تحقیق، اثر افزودن DWP در ۳ سطح ۰، ۴ و ۸ درصد و آنزیم TG در ۳ سطح ۰، ۰/۱۵ و ۰/۳ درصد بر خصوصیات حسی و رنگ نان تافتون بررسی شد. نتایج نشان داد که با افزایش درصد پودر آب‌پنیر دمینرال و گذشت مدت زمان نگهداری، میزان روشنایی (*L) کاهش و قرمزی (*a) و زردی (*b) افزایش یافت (P<۰/۰۰۱). همچنین، با افزایش آنزیم TG، میزان روشنایی (*L) و زردی (*b) افزایش و شدت قرمزی (*a) کاهش یافت (P<۰/۰۰۱). بر اساس نتایج ویژگی‌های حسی، از دیدگاه ارزیابان، افزایش پودر آب‌پنیر تا مقدار ۴ درصد باعث بهبود عطر، بافت و رنگ و افزایش آنزیم TG تا ۰/۱۵ درصد باعث بهبود بافت نمونه‌های نان شد و بنابراین به عنوان بهترین فرمولاسیون جهت تولید نان تافتون مشخص شد.