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ORIGINAL ARTICLE

Improving changes in physical, sensory and texture properties of cake supplemented with purified amylase from fenugreek (*Trigonella foenum graecum*) seeds

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Abstract

Three different concentrations of a purified maltogenic amylase (FSA) from fenugreek (*Trigonella foenum graecum*) seeds were incorporated into the cake formulation. The addition of FSA at 0.003, 0.005 and 0.01 U/g of cake increased the loaf volume, the number of holes (gas cells), and water absorption. Textural study revealed an improvement of the cake quality, resulting in the decrease of hardness and the increase of cohesion. Environmental scanning electron microscopy was performed on different cakes to evaluate the influence of amylase activity on microstructure. The microstructure observation showed that the FSA had a beneficial effect on starch and crumb properties. The sensory evaluation supported this result and confirmed the beneficial effect of adding FSA on cake odor and crust color. In addition, relationships between physical parameters, instrumentally textural parameters, and sensory characteristics of cake treated with FSA might be used for constructing linear regression analysis models to predict overall acceptability. In fact, overall acceptability of treated cake with FSA at 0.01 U appeared to be the most remarkable one and could be a promising technology to improve the quality of cake.

Keywords Fenugreek seeds amylase · Cake · Quality characteristics · Multiple linear regression

Introduction

Enzymes application has gained recognition generally for their widespread uses in various segments of industries (Singh et al. 2017). Various kinds of enzymes were made by microorganisms (Singh et al. 2017) and plants (El Abed et al. 2017; Ben Halima et al. 2015). Interestingly, plant enzymes were more valuable in food applications, including amylolytic enzymes that are produced in large quantities mainly during seed germination (El Abed et al. 2017; Ben Halima et al. 2015).

Amylases are powerful industrial enzymes that account for about 25% of the global enzyme market, ranking second after proteases (Singh et al. 2016). In fact, starch hydrolysis by amylases is the basis for several industrial products such as textile, paper, detergent, distilling industries, digestive aids preparation, pharmaceuticals, starch liquefaction, starch syrups, brewing, baking, and cake production (Wu et al. 2017). Amylases were used to optimize baking properties, enhance the quality of baked products, increase the bread volume, and reduce the staling rate of crumbs (Tsatsaragkou et al. 2017; Pérez-Quirce et al. 2017; Bueno et al. 2016; Giannone et al. 2016).

The used concentration of amylases in baking was established in relation with these hydrolytic modes. For example, the endo amylase was used at low concentration: at 0.01 U/g for *Bacillus licheniformis* amylase and at 0.09 U/g for *Bacillus subtilus* amylase (Leman et al. 2005). However, the exo-amylase was applied with high concentration at 66 U/g for sweet potato beta amylase (Leman et al. 2005). Maltogenic amylases have both endo- and exo-hydrolytic activities, but this ratio varied with amylase characteristics (Mabrouk et al. 2008). The amylase from fenugreek (*Trigonella foenum graecum*) seeds (FSA) used in this study had a high ratio of

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endo/exo-hydrolytic activity. For this reason, a low concentration was used.

In addition, the effect of commercial maltogenic amylase (Novozyme) on textural properties of dough and quality characteristics of white pan bread was investigated by Yoon et al. (2015).

Fenugreek (*Trigonella foenum graecum*) has long been used in traditional Indian and Chinese medicine (Gantait et al. 2014). These seeds have been reported for their management of diabetes (Basch et al. 2003), their richness in antioxidant properties (Kaviarasan and Anuradha 2007), their role in the control of plasma cholesterol level (Madar and Shomer 1990), their stimulating digestive action and hepatoprotective effect (Srinivasan 2006), and in food fortification aiming at providing additional value (Huang et al. 2016). In Tunisia, fenugreek grows in abundance and representing an attractive economic enzymes source. Its seeds have been used to study the presence of maltogenic amylase(s) and its properties for industrial applications (Khemakhem et al. 2013). Compared to other enzymes, maltogenic amylase is unique in yielding significant softness to bread and maintaining a high level of crumb elasticity during storage (Goesaert et al. 2009).

Previously, a maltogenic amylase was purified and characterized from fenugreek (*Trigonella foenum graecum*) seeds by Khemakhem et al. (2013). As part of further search work concerning the application of maltogenic amylase on bakery product, various concentrations of the purified enzyme (FSA) were added on the cake. The present study investigates its beneficial effect with regard to the quality characteristics in terms of physical (bulk density and water absorption), textural (hardness, cohesion, and springiness), microstructural, and sensorial (color, odour, manual texture and overall acceptability) properties. Relationships between physical parameters, textural changes and sensory attributes were also reported.

Materials and methods

Preparation of purified maltogenic amylase

A maltogenic amylase from fenugreek (*Trigonella foenum graecum*) seeds (FSA) was extracted and purified to homogeneity as previously described by Khemakhem et al. (2013). To study the effect of FSA on cake quality, different concentrations were prepared. In particular, the present study investigated the following enzyme concentrations: 0.003, 0.005 and 0.01 U/g of cake.

Amylase activity assays

The amount of the reducing sugars released by the action of amylases on the starch was measured in the standard reaction mixture consisting of 1% (w/v) soluble starch prepared in 0.1 M of sodium acetate buffer and the enzyme solution in a final volume of 1 mL. The concentration of reducing sugar was determined by DNS (3,5-dinitrosalicylate) method at 550 nm (T60Uspectrometer, PG Instruments Ltd) using glucose as standard reducing sugar (Miller 1959). One unit of amylase activity was defined as the amount of enzyme required to produce reducing sugars equivalent to 1 μmol/min under these reaction conditions.

Cake preparation

The basic formula of cake (El Abed et al. 2017; Ayadi et al. 2009; Sudha et al. 2007) including 100 g of durum wheat flour, 100 g sugar, 120 g fresh egg, 25 g shortening, 40 g refined vegetable oil, 0.5 g Vanoise baking powder, and 1.5 g salt was used. Cake batter was prepared in a Hobart mixer (N-50) using flour batter method, wherein, the flour, shortening, salt and baking powder were creamed together to get a fluffy cream; eggs and sugar were whipped together until getting semi-firm foam. The sugar–egg foam was mixed with the creamed flour and shortening, after which the vegetable oil was added in small portions. Cake batter was poured into a wooden pan and baked at 160 °C for 1 h. Four independent lots of cakes were prepared with different concentrations of FSA (0, 0.003, 0.005 and 0.01 U/g per cake batter) which were incorporated into the cake formulation. For each experiment, all assays were applied to a single batch of cake. Each formulation produced one mixture homogeneous which was performed in triplicate. Cake samples were analyzed for water absorption, bulk density, texture profile analysis: hardness, cohesion and springiness, and sensory attributes (color, odour, manual texture and overall acceptability). The number of total samples analysed was 36: $(4\times3)\times3$ trials were used. In fact, for physical properties, texture profile analysis and sensory evaluation, a 12 (4×3) trials were used and obtained as follows: four treatments [Control (C) and three treated samples (T1–3)].

Physical properties of prepared cake

Volume (v, cc) of cakes was measured using the rapeseed displacement method. Cake weight was measured (w, g) and the density (w/v, g/cc) was calculated (Chen et al. 1988). To determine water holding capacity (WHC), 1 g of cakes was mixed with 50 mL of distilled water vigorously for 1 min and then centrifuged for 15 min at 10,000×*g* at 20 °C. The supernatant was discarded and the tube was kept inverted for 25 min at 50 °C. The WHC was expressed as g of water bound per gram of the sample on dry basis (Chen et al. 1988).

Texture measurement

A texture procedure analysis (TPA) test was performed using a texture analyzer (Texture Analyzer: LLOYD instruments, England) equipped with a 1000 (N) load cell and 0.05 (N) detection range. Sample of dough was transferred into a molded Nalgene polypropylene tube (5 cm height) that was placed in a fixture to hold it in place under the Texture Analyzer. An acrylic cylindrical probe was used to compress the top surface of the cake sample by 50% of its original height (40 mm) at a speed of 10 mm/s. The Texture analyzer was interfaced with a computer, which controls the instruments and analyses the data using the software supplied by Texture Technologies Corp. Hardness (N: peak force required for first compression), springiness (mm: distance sample recovers after the first compression) and Cohesiveness (dimensionless: ratio of the positive force zone during the second compression to that of the first compression excluding the areas under the decompression portion of each cycle) were determined according to Ayadi et al (2009).

Microstructure observations

Small cake samples (1 cm long and 1 cm in diameter) were cut from the center and used to perform microscopic observations. Cake microstructure was examined by Environmental Scanning Electron Microscopy (ESEM) (Philips XL 30 ESEM, Japan). ESEM allows the observation of samples in their natural state or under controlled conditions of temperature and pressure. The environmental mode does not require any preliminary preparation; in addition, this mode removes completely the electronic load effects on the surface and thus preserves the native structure and content of the sample. In this study, microscopic observation was carried out under vacuum (pressure = 0.1 kPa). Cake sample was fixed to the support using double side adhesive tape. A large number of micrographs were taken to select the most representative ones.

Sensory analysis

The organoleptic characteristics of cakes were investigated by 36 non-trained panelists (16 male and 20 female, age range 25–45 years both). They were asked to evaluate the products for crust color, odor, texture, and overall acceptability (Sudha et al. 2007). Assessors evaluated color, appearance, manual and oral texture, flavor, and overall acceptability using a 5-point scale. The ratings were on 5-point hedonic scale ranging from 5 (like extremely) to 1 (dislike extremely) for each organoleptic characteristic.

Statistical analysis

A one-way analysis of variance (ANOVA) and Turkey's post hoc test were performed to determine significant differences between the treatments using SPSS 19 statistical software (SPSS Ltd., Woking, UK). Means and standard errors were calculated. Differences among the mean values of the various treatments were determined by the least significant difference test. A probability level of $P < 0.05$ was used to test the statistical significance of all experimental data. Mean differences were separated by the least significant difference (LSD) procedure. Pearson correlation coefficients were generated to describe the relationship between physical parameters and the instrumentally texture measured parameters. Multiple linear regression analysis were performed using a Durbin–Watson statistic tests, at 95% of confidence level, to determine the relationships between instrumentally textural parameters and physical parameters on the one hand, and between overall acceptability and sensory parameters of formulated cake on the other hand.

Results and discussion

Observations of cakes

Figure 1a shows images of cakes made with different levels of FSA incorporation. This figure presented a change in cake crust color. Indeed, with the increase of FSA concentration, a cake crust color was intensified particularly at 0.01 U/g. In fact, it was demonstrated that the added amylases increased the level of reducing sugars in flour and dough, thus promoting the formation of Maillard reaction products, which, in their turn, intensified crust color (Goesaert et al. 2009). In addition, El Abed et al (2017) demonstrated that the crumb structure was found to be improved after amylase of the parthenocarpic date application. Increasing the level of enzyme (0.018 U/g) not only darkened the cake crust, but also increased the crumb stickiness, which was probably associated with glucose produced as a result of amylase activity.

Cross-sections views were presented in Fig. 1b. This figure demonstrates that dough with added 0.005 and 0.01 U/g of FSA exhibited a better overall gas retention profile than in the control test. The presence of these gas holes could have a great influence on the physical properties of made cakes such as density and water holding capacity. As explained by Bedoya et al (2014), cakes added with maltogenic amylase remained in a positive way, in terms of appearance. The same results were obtained by El Abed et al (2017) since the addition of amylase from parthenocarpic date caused a

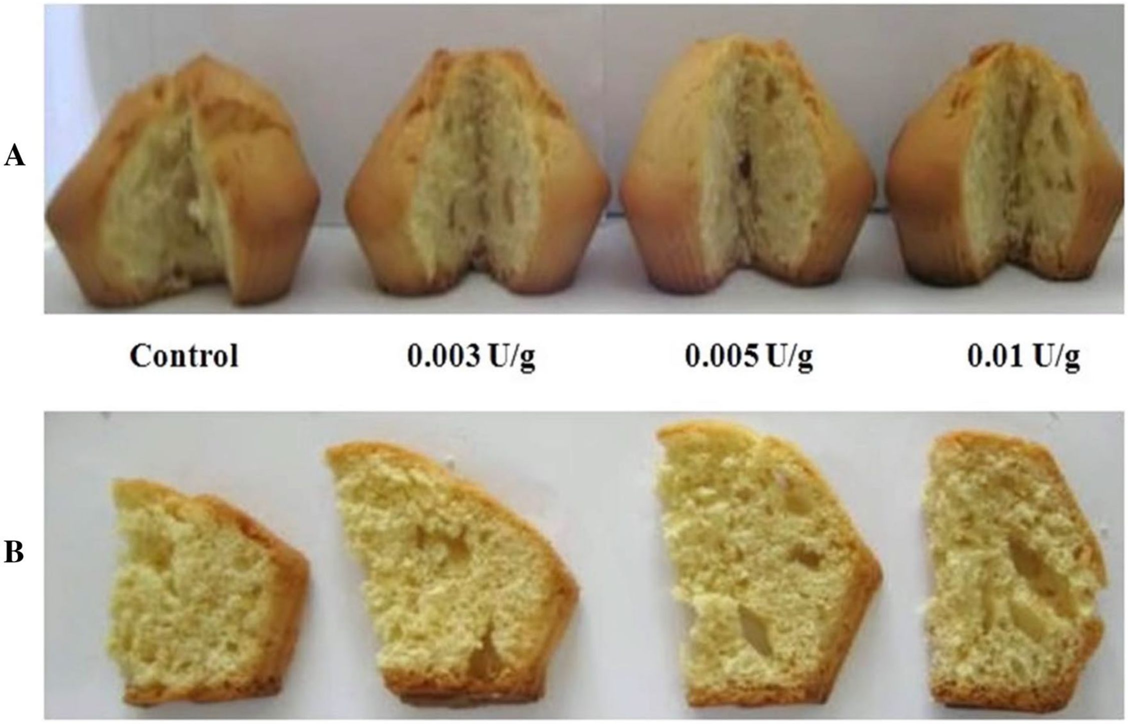

Fig. 1 Overall observations (**a**) and cross-section views (**b**) of cakes prepared with purified maltogenic amylase (FSA) from fenugreek at 0.003, 0.005 and 0.01 U/g

more open crumb grain, cohesive dough and internal resistant structure, thus resulting in better gas retention capacity. The enhancement of gas retention capacity of dough could favor better texture and cake volume.

Physical properties of cakes

Table 1 shows the physical properties (water absorption (%), and bulk density (g/cm^3) and texture profile analysis [hardness (N), cohesion and springiness (mm)] of cake. Bulk density is defined as weight of fiber per unit volume, often expressed as g/cm^3, and is a good index of structural changes (Sreerama et al., 2009). The density of cakes was reduced from 0.94 to 0.52 cm^3 with addition of purified FSA at 0.003, and 0.01 U/g, respectively. It was found that Water absorption rose from 18 to 39% due to 0.005 and 0.01 U/g of FSA addition, respectively. Laurikainen et al (1998) reported an increase in water absorption with increased levels of fungal and bacterial enzyme addition in bread making. In addition, Martinez-Anaya and Jimenez (1997) demonstrated that starch and non starch hydrolyzing enzymes resulted in the release of free water and the change in the soluble fraction of dough. These effects were apparent immediately after mixing and continued during resting, which changed viscoelastic properties of dough. A significant difference ($P < 0.05$) was observed between control and fortified cakes with FSA concerning weight (Table 1). Generally, the weight loss of cakes after baking is directly related to water loss. Indeed,

Table 1 Effect of FSA addition at 0.003, 0.005 and 0.01 U/g on physical properties (water absorption (%), and bulk density (g/cm^3) and texture profile analysis [hardness (N), cohesion and springiness (mm)] of cake

Treatment	Physical properties		Texture profile		
	Bulk density	Water absorption	Hardness	Cohesion	Springiness
Control	0.94 ± 0.06^a	1.21 ± 0.05^a	9.322 ± 1.45^a	0.353 ± 0.002^a	12.788 ± 1.11^a
T1	0.62 ± 0.05^b	1.22 ± 0.04^a	8.432 ± 1.65^b	0.452 ± 0.003^b	12.645 ± 1.32^a
T2	0.52 ± 0.06^c	1.45 ± 0.01^b	8.231 ± 1.03^b	0.481 ± 0.003^b	12.044 ± 1.2^b
T3	0.52 ± 0.03^c	1.69 ± 0.02^c	6.342 ± 1.22^c	0.549 ± 0.002^c	11.313 ± 0.07^c

±: Standard deviation of three replicates

a–c: Averages with different letters in the same row, for each parameter, are different ($P < 0.05$)

(C) Control, (T1) 0.003 U/g of FSA, (T2) 0.005 U/g of FSA and (T3) 0.01 U/g of FSA the quantity of water necessary for dough hydration depends on the rate of enzyme addition during baking.

Influence of FSA on texture and microstructure of cakes

Textural evaluation of cakes, containing 0.003, 0.005 and 0.01 U/g, such as hardness, cohesion, and springiness are presented in Table 1. The hardness of the fortified cakes samples was lower ($P < 0.05$) than that of the control. In fact, it should be noted that treated cakes with 0.01 U/g showed a slight decrease in hardness ($P < 0.05$) and springiness ($P < 0.05$) values: from 9.322 ± 1.45 N and 12.788 ± 1.11 mm for the control cake to 6.342 ± 1.22 N and 11.313 ± 0.07 mm. In contrast, cohesion was increased from 0.35 for the control cake to 0.54 for the amylase treated cake with the concentration of 0.01 U/g. Similar results were obtained by Yoon et al (2015) using industrial maltogenic amylase from Novozymes. Indeed, a decrease in hardness of the maltogenic amylase infused bread was observed. After several minutes of baking, the surface of the dough dried up to 130–160 °C and the phenomena of browning appeared and therefore enhanced by the release of reducing sugars by the amylase activity leading to an increase in crust hardness. In addition, Goesaert et al (2009) reported that the *B. stearothermophilus* maltogenic alpha-amylase limits amylopectin recrystallisation, and consequently the water immobilization. However, the addition of amylase from parthenocarpic date (AmyPF) does not have a significant impact on cohesion and springiness, suggesting that AmyPF does not alter the textural properties of wheat flour (El Abed et al. 2017). Similar results were observed with amylase from oat (*Avena sativa*) seeds, which improved the baking characteristics of bread without affecting wheat flour properties (Ben Halima et al. 2015).

To better understand the influence of FSA on the structural and textural modification for extrudate with/without enzyme fraction, ESEM was used to investigate the cell morphology of the formulated cake (Fig. 2a, b).

In the control sample, dough structures were smooth and free from pores and cracks and they had oval shapes (Fig. 2a, b). Hence, differences were observed between control cake and the FSA-supplemented cakes. Therefore, FSA had a profound impact on starch and crumb properties promoting the effects of carbon dioxide. During baking, FSA induced an improvement of pores gas cells produced by carbon dioxide. Cracks in the granules were observed after baking. This gas expanded the dough by creating multiple cavities and gave it soft properties. On the other hand, FSA can hydrolyse internal amylopectin chains, with release of clusters from the structure (dextrin) (Leman et al. 2009).

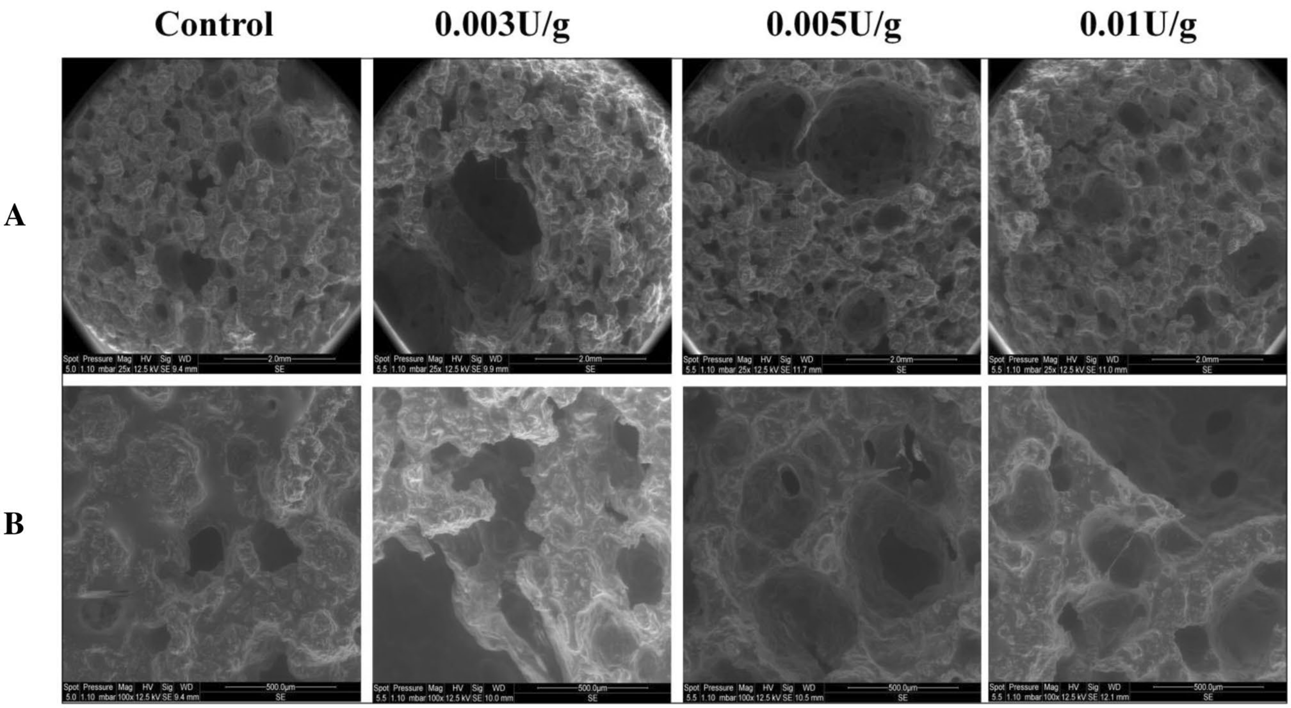

Fig. 2 Microstructure of the control cake and cakes prepared from dough supplemented with FSA at 0.003, 0.005 and 0.01 U/g. **a** 2 mm scale bars of ESEM; **b** 500 μm scale bars of ESEM

Sensory analysis

Sensory perception of food product is a critical parameter that determines its acceptability. In fact, a good texture and tasteful product influence the consumer-buying behavior. The results of sensory analysis of cakes supplemented with FSA at different concentrations are presented in Table 2. No significant ($P > 0.05$) impact on cakes color and odor was observed except for cakes supplemented with 0.01 U/g, which showed an increase in score. In fact, the added amylase increased the level of fermentable and reducing sugars in flour and dough, thus promoting the formation of Maillard reaction products, which intensify cake flavor and crust color. However, average scores for texture and aspect showed that panelists' acceptability of cakes increased with FSA addition even with only 0.003 U/g. Those results were in accordance with that of the textural and microstructure studies. With the increase in the level of FSA in formulation, the sensory scores for organoleptic characteristics of cakes increased ($P < 0.05$). As presented in Table 2, T3 showed the highest overall acceptability score (3.86 ± 0.17), followed by the samples fortified with 0.005 U/g of cake (3.78 ± 0.15). Indeed, treatments had a significant effect ($P < 0.05$) on overall acceptability of cake samples. Courtin and Delcour (2002) reported higher bread scores for enzyme supplemented breads as compared with control. In addition, Bedoya et al. (2014) confirmed that the cakes fortified with maltogenic amylase showed the highest score for the attribute appearance, which influenced consumer purchase intention.

Linear regression analysis

Relationship between instrumentally textural and physical parameters

For control samples, physical parameters showed a strong correlation ($P < 0.01$) with hardness (Table 3). In this case, hardness was correlated positively with water absorption ($P < 0.01$) and negatively with bulk density ($P < 0.01$). Furthermore, significant negative linear correlations ($P < 0.01$) of $r = -0.666$, $r = -0.688$ and $r = -0.698$ for T1, T2 and T3, respectively, were observed between the bulk density and hardness, and significant positive linear correlations ($P < 0.01$) of $r = 0.898$ (T1), $r = 0.987$ (T2) and $r = 0.965$ (T3) were found between water absorption and hardness of cake treated with purified amylase. Physical parameters were strongly correlated with hardness. In this part, multiple linear regressions were developed to predict instrumental hardness.

The predicted hardness, major sensory restraint for consumer rejection, was selected and the stepwise multiple regression analysis was used to predict the instrumental hardness as a function of bulk density and water absorption values and color.

As shown in (Table 4, I), multiple linear regression analysis revealed a high correlation ($R^2 > 0.7$) between hardness (dependent variable) and physical parameters (independent variables). For control and treated samples, water absorption had a positive effect on the hardness, while the bulk density had a negative linear proportionality. In fact, the regression coefficients of water absorption for T1–3 samples were higher than control. Water absorption of T3 samples was 1.43 (10.708/7.453) and 1.14 (10.708/8.122) times higher than those of T1 and T2 samples. It was also concluded that treatment with maltogenic amylase increased the bulk density impact on hardness compared to control samples.

Table 2 Effect of three concentrations (0.003, 0.005 and 0.01 U/g) of purified FSA on sensory attributes cakes

	Color	Odour	Manual texture	Overall acceptability
Control	3.53 ± 0.11^a	3.55 ± 0.1^a	3.28 ± 0.11^a	3.42 ± 0.11^a
T1	3.67 ± 0.18^a	3.57 ± 0.09^a	4.18 ± 0.13^b	3.54 ± 0.09^b
T2	3.66 ± 0.06^a	3.58 ± 0.08^a	3.94 ± 0.11^b	3.78 ± 0.15^c
T3	3.98 ± 0.08^b	3.96 ± 0.05^b	4.15 ± 0.15^b	3.86 ± 0.17^c

±: Standard deviation of three replicates

a–c: Averages with different letters in the same row, for each parameter, are different ($P < 0.05$)

(C) Control, (T1) 0.003 U/g of FSA, (T2) 0.005 U/g of FSA and (T3) 0.01 U/g of FSA

Relationship between manual texture and instrumentally textural parameters

For both treated (T1–3) and untreated (C) samples, there was a positive and significant correlation ($P < 0.01$) between hardness, cohesion, and springiness (Table 3). All instrumentally textural parameters (hardness, cohesion and springiness) have a positive effect on the predicted manual texture (Table 4, II). The manual texture analyzes aims at the physical examination of baked products which gives direct information about the product quality and these products were judged by the customer (Carson and Sun 2001; Szczesniak 2002). Furthermore, the regression coefficients of odor for T1, T2 and T3 samples were higher than control (II). The treatment with FSA at 0.01 U/g (T3) improved significantly all instrumentally textural parameters (Table 4, II).

According to equations (Table 4, I and II), the predicted manual texture equations of control and treated samples (C, T1, T2 and T3) could be written as indicated in Table 4, III.

Table 3 Pearson's correlation coefficients between physical parameters and the instrumentally texture measured parameters

	Bulk density	Water absorption	Hardness	Cohesion	Springiness
Bulk density C	1				
T1	1				
T2	1				
T3	1				
Water absorption C	− 0.701**	1			
T1	− 0.744**	1			
T2	− 0.821**	1			
T3	− 0.826**	1			
Hardness C	− 0.658**	0.874**	1		
T1	− 0.666**	0.898**	1		
T2	− 0.658**	0.987**	1		
T3	− 0.698**	0.965**	1		
Cohesion C	0.452	0.325	0.758**	1	
T1	0.549*	0.365	0.798**	1	
T2	0.566*	0.415	0.801**	1	
T3	0.577*	0.505*	0.821**	1	
Springiness C	0.365	0.569*	0.905**	0.907**	1
T1	0.369	0.599*	0.912**	0.908**	1
T2	0.441	0.536*	0.932**	0.929**	1
T3	0.452	0.529*	0.935**	0.926**	1

(C) Control, (T1) 0.003 U/g of FSA, (T2) 0.005 U/g of FSA and (T3) 0.01 U/g of FSA

*$P < 0.05$

**$P < 0.01$

Relationship between overall acceptability and sensory parameters

Due to its importance in the development and marketing of food product, overall acceptability is judged on the basis of several factors, including textural parameters and physical properties such as color and manual texture. Moreover, the overall acceptability evaluation must be performed to relate the consumer's acceptance for a product to laboratory data (IFIS, 2009). In this part, the multiple linear regression analysis using the overall acceptability parameter as a dependent variable was performed. Sensory analyses (color, manual texture and odor) were considered as independent variables. The multiple linear regression analysis (Table 4, IV) revealed a high correlation ($R^2 > 0.863$) between overall acceptability and all parameters. As shown in equations (Table 4, IV) for treated and control samples, manual texture, color, and odor have a positive effect on the overall acceptability. The regression coefficients of all sensory attributes for T1–3 samples were higher than control (Table 4, IV). Furthermore, manual texture of T3 samples was 1.467 (2.698/1.839) and 1.213 (2.698/2.223) times higher than those of T1 and T2 samples. Similarly, T3 significantly improved color and odor (Table 4, IV).

According to equations describing the (i) relationship between manual texture and instrumentally textural parameters (Table 4, III) and (ii) relationship between overall acceptability and sensory parameters (Table 4, IV), the predicted overall acceptability of control and treated samples could be written as indicated in the equations mentioned in Table 4, V. On other hand, according to the obtained results and as shown in Table 5, OAT1 was 1.061 times higher than OAC. In addition, OAT2 was 1.207 times higher than OAT1. It should be noted that an increase of FSA concentration (T1–3) resulted in a positive effect on color and odor. OAT3 was 1.207 and 1.214 times higher than OAT1 and OAT2, respectively, accompanied by positive effects of color (5.639) and odor (1.754). In fact, acceptability of T3 appeared to be the most remarkable one and could be presented as follows:

Overall acceptability (T3) = 1.773 + 1.214 × OAT2 + 2.639 × Color + 1.7540.07 × odour (Table 5).

Conclusion

The influence of purified maltogenic amylase (FSA) from fenugreek (*Trigonella foenum graecum*) seeds addition on cake volume, water binding capacity, textural parameters, microstructure, and sensory properties was studied. Results showed that FSA addition has beneficial effects such as reduction in the bulk density, hardness, and springiness,

Table 4 Multiple linear regression equations of (i) textural parameters versus physical parameters, (ii) manual texture versus instrumentally textural parameters and (iii) overall acceptability versus sensory parameters of cakes

Relationship between instrumentally textural parameters and physical parameters	
I	
Predicted hardness (C)	− 31.379 – 47.833 × bulk density + 5.188 × water absorption ($R^2=0.707$)
Predicted hardness (T1)	15.375 − 30.864 × Bulk density + 7.453 × Water absorption ($R^2=0.997$)
Predicted hardness (T2)	15.008 − 25.102 × Bulk density + 8.122 × Water absorption ($R^2=0.713$
Predicted hardness (T3)	11.564 − 22.194 × Bulk density + 10.708 × Water absorption ($R^2=0.885$)
Relationship between manual texture and instrumentally textural parameters	
II	
Predicted manual texture (C)	3.058 + 0.441 × hardness + 4.784 × cohesion + 0.259 × springiness ($R^2=0.913$)
Predicted manual texture (T1)	− 2.101 + 0.671 × hardness + 7.300 × cohesion + 0.410 × springiness ($R^2=0.865$)
Predicted manual texture (T2)	22.541 + 0.685 × hardness + 7.853 × cohesion +0.444 × springiness ($R^2=0.939$)
Predicted manual texture (T3)	− 5.549 + 0.707 × hardness + 8.627 × cohesion + 0.701 × springiness ($R^2=0.886$)
III	
Predicted manual texture (C)	− 10.78 − 21.091 × bulk density + 2.88 × water absorption + 4.784 × cohesion + 0.259 × springiness
Predicted manual texture (T1)	8.215 − 20.709 × bulk density + 5.001 × water absorption + 7.300 × cohesion + 0.410 × springiness
Predicted manual texture (T2)	34.821 − 17.181 × bulk density + 5.563 × water absorption ++7.853 × cohesion + 0.444 × springiness
Predicted manual texture (T3)	34.821 − 17.181 × Bulk density + 5.563 × Water absorption ++7.853 × Cohesion + 0.444 × Springiness
Relationship between overall acceptability and sensory parameters	
IV	
Predicted overall acceptability (C)	7.026 + 1.733 × manual texture (C) + 1.16 × color + 1.005 × odour ($R^2=0.955$)
Predicted overall acceptability (T1)	3.27 + 1.839 × manual texture (T1) + 4.557 × color + 1.434 × odour ($R^2=0.903$)
Predicted overall acceptability (T2)	1.235 + 2.223 × manual texture (T2) +5.023 × color + 1.734 × odour ($R^2=0.958$)
Predicted overall acceptability (T3)	3.27 + 2.698 × manual texture (T3) +5.555 × color + 2.034 × odour ($R^2=0.863$)
V	
Predicted overall acceptability (C)	− 11.655 − 36.551 × bulk density + 4.991 × water absorption + 8.291 × cohesion + 0.448 × springiness + 1.16 × color + 1.005 × odour
Predicted overall acceptability (T1)	18.377 − 38.083 × bulk density + 9.195 × water absorption + 13.424 × cohesion + 0.753 + 0.410 × springiness + 4.557 × color + 1.434 × odour
Predicted overall acceptability (T2)	78.462 − 38.193 × bulk density +12.366 × water absorption + 17.457 × cohesion + 0.987 × springiness + 5.023 × color + 1.734 × odour
Predicted overall acceptability (T3)	10.354 − 42.334 × bulk density + 20.426 × water absorption + 23.275 × cohesion + 1.891 × springiness + 5.555 × color + 2.034 × odour

and an increase in water absorption and cohesion. Moreover, FSA addition causes a significant change in cake macro- and microstructure (crust color, size and number of holes). The overall acceptability rate showed that a 0.01 U/g maltogenic amylase resulted in an increase in total sensory scores. Relationships between physical parameters, instrumentally textural parameters and sensory characteristics of cake treated with purified amylase could be used for constructing linear

Table 5 Multiple linear regression equations of overall acceptability of different treatments of cake

Dependent variable	Independent variable	Regression coefficient
OAC	Constant	7.026
	Manual texture	1.733
	Color	1.16
	Odour	1.005
OAT1	Constant	− 4.185
	OAC	1.061
	Color	3.327
	Odour	1.328
OAT2	Constant	− 2.717
	OAT1	1.207
	Color	4.285
	Odour	1.333
OAT3	Constant	1.773
	OAT2	1.214
	Color	5.639
	Odour	1.754

OAC overall Acceptability of control samples, *OAT1* Overall Acceptability of T1, *OAT2* Overall Acceptability of T2, *OAT3* Overall Acceptability of T3

regression analysis models to predict overall acceptability. The addition of maltogenic amylase notably at 0.01 U/g improved cake quality. The new cake supplemented with purified FSA proved to exhibit a number of promising properties and attributes that might open new opportunities to get more efficient, safe, and cost-effective food products.

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Conflict of interest The authors declare that they have no conflict of interest in the publication.

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