Original paper

Optimization of the Level of Chickpea Sourdough and Baking Powder in Cake Formulation by Response Surface Methodology: Effects on Physicochemical, Sensory and Antioxidant Properties

Müge Hendek ERTOP^{1*} and Mehmet HAYTA²

¹Kastamonu University, Faculty of Engineering and Architecture, Dept. of Food Engineering, Kastamonu, Turkey

²Erciyes University, Faculty of Engineering, Dept. of Food Engineering, Kayseri, Turkey

Received November 6, 2017 ; Accepted March 29, 2018

The chickpea sourdough, also known as “sweet yeast”, has not been experimented in chemically leavened bakery products such as cake so far, although it has been used in traditional breads. The aim of this study was to optimize the amounts of chickpea sourdough (A) and baking powder (B) in cake formulation and by examining various quality parameters. An experimental design suggested by Response Surface Methodology, Central Composite Design was used for optimization. The optimization results were validated experimentally. The cake, produced according to the optimized model (OC) was compared with the control cake (CC) in terms of various quality parameters. According to the results, optimum levels of usage were 64.02 g for A and 5.97 g for B. Smaller and more homogeneous pore structures were obtained in OC texture by the use of A according to the image analysis. The cake also acquired slightly sour, sweetish and soft sensory profiles. DPPH radical scavenging activity and physicochemical properties were also improved by the use of the chickpea sourdough.

Keywords: antioxidant activity, chickpea, image analysis, response surface methodology, sourdough

Introduction

The chickpea sourdough is a traditional method also known as “sweet yeast” or “chickpea yeast” and is a well-known method used in various Mediterranean and Balkan countries (Pasqualone *et al.*, 2004). The “sweet yeast” is a traditional and regional name. It quite likely originate from sweet taste and light flavour of the end-product produced by chickpea sourdough. Because, the taste and flavor characteristic of products vary depending on the type of sourdough (raw material such as, rice, wheat or chickpea; process condition; sourdough form such as wet, dried etc.), its microbiota and their metabolites. It is a kind of sourdough which has been used in bread making as a leavening agent and for imparting a distinctive flavor and taste. The chickpea sourdough may also prolong shelf life and provides functional, nutritional and textural quality to bakery products (Sıkılı, 2003). The synthesis of microbial metabolites such as peptides and amino acid

derivatives, activation of enzymes, acidification and proteolysis cause several changes during sourdough fermentation, which positively affect the dough and product, and they influence the functional and nutritional quality (Gobbetti *et al.*, 2014). Nowadays, the literature is particularly rich in results and this shows how the sourdough may affect the functional features of baked goods leavened with bakery yeast. Moreover cereals and legumes such as chickpea are an important part of the daily diet and mainly provide nutrients and functional compounds (Coda *et al.*, 2015). Although legumes have been components of the dietary customs of many countries for thousands of years, their usage and their nutritional and functional values have only recently started to be rediscovered and investigated using suitable techniques (Curiel *et al.*, 2015). The chickpea has a high-quality protein content (Gomez *et al.*, 2008) and protein bioavailability due to its well-balanced amino acid composition than many of the several legume seeds (Roy *et al.*, 2010). The

*To whom correspondence should be addressed.

E-mail: mugeertop@kastamonu.edu.tr

chickpea is rich in Ca, P, Mg, K, and is also a good source of important vitamins such as riboflavin, niacin, thiamin, folate, the vitamin A precursor β -carotene and the amino acid histidine (Jukanti *et al.*, 2012). In this respect, the usage of chickpea sourdough will satisfy consumers' natural and healthy product expectations as a natural ingredient.

Some of previous studies have investigated the addition of pea, chickpea or their flours to several bakery products such as chapatti, cakes (Gomez *et al.*, 2008; Hera *et al.*, 2008), biscuits, bread (Rizzello *et al.*, 2014a) and crackers (Pasqualone *et al.*, 2004; Hera *et al.*, 2008; Kadam *et al.*, 2012). However, the studies concerning chickpea fermentation or bakery products contained chickpea sourdough are very limited (Tulbek, 2006; Kefalas *et al.*, 2009). Furthermore, the sourdough usage in bakery products leavened with baking powder like cake is not a general application. In this study, the optimized level of chickpea sourdough and baking powder in the cake formula was determined in terms of volume (V) and acceptability value (AV), and the effects of chickpea sourdough on cake quality properties were examined.

Materials and Methods

The wheat flour (Cesur Milling Co., Trabzon, Turkey) used for cake production had 14.3 % moisture, 0.63 % ash, 9 % gluten and 80 % gluten index. The baking powder (Dr. Oetker) and other ingredients such as chickpea (*Cicer arietinum* L.) cv. Koçbaşı were purchased from a local supermarket. The chemicals used for analysis were supplied by Merck Group (Germany).

Experimental design and optimization The amounts of baking powder and chickpea sourdough utilized were considered as two independent factors and two main responses were Volume (V) and Acceptability values (AV). The main effect of the levels of baking powder and chickpea sourdough which were optimization factors, on cake properties was "volume (V)". Moreover, the chickpea sourdough was first time used in a cake formulation which was a chemically leavened product. For that reason, the consumer acceptance was considered and therefore the AV was determined as a parameter regarding sensory properties of cake samples. Response surface methodology (RSM)-Central composite rotatable design (CCRD) desirability function was used for the effect of the two factors on the two responses (Design Expert 7.0.0, Stat-Ease Inc., Minneapolis, USA). The experimental levels of factors were for B: 0, 1.37, 4.66, 7.96, 9.33 g, for A: 0, 14.64, 49.99, 85.34, 99.98. The two factors and five replicates at the center point led to a set of 13 experiments. The cake samples were produced according to the experimental design. The V and AV results were evaluated by software, and the optimized results were calculated.

Preparation of chickpea sourdough (A) The method used traditionally to prepare chickpea sourdough was slightly modified. 100 g chickpea with 100 mL water was soaked for

12 h and then milled with a laboratory blender (Bosch MMR15A1, Germany). It was mixed with the same amount of water. Salt (2 g), sugar (10 g) and wheat flour (50 g) were added and incubated at 26 °C for 12 h, pH up to 4.5. It was filtered by stainless steel strainer and approx. 280 g filtrate was obtained. It was mixed with wheat flour (140 g), then incubated at 26 °C for 6 h, pH up to 4.5. Because the sourdough fermentation especially performed in the presence of low values of pH (e.g., 3.5–4.5), (De Angelis *et al.*, 2007; Maioli *et al.*, 2008; De Angelis *et al.*, 2009; Najjar *et al.*, 2009; Lappi *et al.*, 2010), in this study, A was incubated up to pH 4.5.

Enumeration of lactic acid bacteria (LAB) and yeast For determination of numbers of LAB, the elective media MRS agar (Merck, Germany) was used. Appropriate dilutions were plated on MRS agars and the plates incubated anaerobically at 35 °C for 48–72 h. For yeast counting, appropriate dilutions were plated on YGC agar (Merck, Germany), incubated (JSR JSBI-C, Korea) aerobically at 25 °C for 72 h. Then the colonies were counted (Lönner *et al.*, 1986; Simsek *et al.*, 2006).

Preparation of cake samples The method described by Sudha *et al.* (2007) was used for making the cake. The formula included 133 g flour, 133 g sugar, 180 g egg, 53 g milk, 33 g shortening, 50 g refined vegetable oil, and 2 g salt. The levels of A and B were calculated and added according to the experimental design (Table 1). The CC without A was also prepared with the basic formula contained 9.33 g of B for comparing with OC. The batter was prepared by flour batter method, where in the flour, shortening, refined vegetable oil, baking powder, salt and chickpea sourdough were mixed (Kitchen aid, KSM150PSER, Belgium). Eggs and sugar were whipped together until a semi-firm foam resulted. The sugar-egg mix and milk were added to the creamed flour. The cake batter was poured into a rectangular cake pan and baked in a preheated oven (Kenwood, NW796, China) at 175 °C for 40 min.

Quality properties of the cakes

Pore structure Images of both faces of the two central slices (20 mm thickness) from each loaf were captured using a flatbed scanner (Model Scanjet 8200, HP, Cupertino, USA) with a resolution of 600 dots per inch (dpi) and converted from the true color to grayscale. The cake sample images were calibrated, standardized and optimized by applying the appropriate filters in order to measure the pore's size and distribution using Image-Pro Plus 6.0 (Media Cybernetics Inc., USA) software. The number and the area of pores were characterized by enumerating the pores present in six pre-selected dimensional classes based on area (class 1= 0.05–0.49 mm², class 2= 0.50–0.99 mm², class 3= 1.00–4.99 mm², class 4= 5.00–9.99 mm², class 5= 10 – 49.99 mm², class 6= >50 mm²) as previously described (Bianchia *et al.*, 2008). The number and the area of the pores and the percentages thereof were calculated by the software. The pore area and numbers were then classified by Microsoft Excel (Office 2007,

Microsoft Corp, Redmond, WA).

Volume (*V*), specific volume and crust thickness The *V* of cakes cooled under room conditions for 1 h after baking were determined by using the method based on displacement with rape seeds. Their weights were measured. The specific volumes of cakes were calculated by using the formula (Artan *et al.*, 2010; Torrieri *et al.*, 2014). The crust thicknesses of the samples were measured at five different points with a digital caliper (Asimeto, Germany).

Acceptability value (*AV*) For calculating of *AV*, the panel test was carried out to determine that various properties of the cakes. The hedonic scale used by Olapade and Adetuyi (2007) was slightly modified. Twenty trained panelists having prior experience of testing bakery products assessed (Ndife *et al.*, 2011) the features of cakes, such as crust color, baking quality, symmetry, and internal features such as structural homogeneity, crumb color, taste and aroma. The samples were labeled randomly with three-digit numerical codes and then given to the panelists. Each of 10 attributes was scored using a 10-point hedonic scale, and total *AV* was calculated out of maximum 100 points.

pH and total titratable acidity (*TTA*) The cake and the distilled water were mixed in a weight: volume ratio of 1:9. The mixture was crumbled by ultra turrax (IKA, T25, Germany) until a homogeneous mixture was obtained. The mixture was then kept for 10 minutes and the pH was measured with a pH meter (Heidolph, Germany). The mixture was titrated with 0.1 N NaOH by adding phenolphthalein and then *TTA* was calculated (Rizzello *et al.*, 2016).

Moisture After 3 h of baking, a slice was taken from the cake (Poinot *et al.*, 2008). The crust and the crumb were homogenized, and 5 g were weighed out. Moisture was determined by oven (Microtest MST55, Turkey) drying at 105 °C to constant weight (Akgün and Doymaz, 2005). The cake samples were stored at the same conditions (24±2 °C, kept away directly sunlight). Moisture loss during shelf life was also determined between days 1 and 5.

Color (*L, *a**, *b**)** The color profile for crust and crumb of cake samples was determined using a colorimeter (Konica-Minolta, CR400, Japan) in the form of *L**, *a** and *b**. The measurement was carried out on five points from crust and crumb, and mean values were calculated (Torrieri *et al.*, 2014; Rizzello *et al.*, 2014b).

Antioxidant activity α , α -diphenyl- β -picrylhydrazyl (DPPH) radical scavenging activity method was performed. Soxhlet extraction with petroleum ether was used to remove the oil from cake samples (Sudha *et al.*, 2007). For determination of radical scavenging activity, 10 mg of DPPH was dissolved in 25 mL of 80 % methanol. 0.2 mL of the sample extract was mixed with DPPH solution and 4 mL of 80 % methanol and kept in the dark at room temperature for 30 min. The absorbance (*A* sample) was recorded at 517 nm through UV-VIS spectrophotometer (Agilent, UV-Visible,

USA). The blank sample was prepared using 0.1 mL of methanol and 3.9 mL of DPPH solution and its absorbance (*A* control) was also recorded. DPPH radical scavenging activity was calculated using the formula (Eq.1) (Karamac *et al.*, 2002).

$$\text{DPPH scavenging (\%)} = [1 - (\text{A sample}/\text{A control})] \times 100 \quad \text{-----Eq. 1}$$

Sensory profile The sensory profile analysis was carried out for the aim of determination of differences between the optimized and control cake samples. The intensities of the various sensory characteristics of cake samples were evaluated by panelists. Sensory evaluation of the cakes, which was modified according to Volpini-Rapina *et al.* (2012), was performed by a panel of 20 male and female volunteers having prior experience of testing bakery products. It was taken into consideration for the panelist selection that their liking and usage of the product, age (between 18-45), no allergies to bakery products or used ingredients. The samples were labeled randomly with three-digit numerical codes and then given to the panelists, who evaluated the intensities of attributes for each cake. The intensities (sweet, fatty, sour/acidic, soda, malty, egg, overall) were scored using a 5-point hedonic scale. Five means extreme perceptible and zero means imperceptible. The results were presented by sensory diagrams.

Statistical analysis After optimization, the results were validated experimentally. The cake sample produced by the optimized model was evaluated in terms of physicochemical and sensory profile analysis in comparison with the control sample. The one sample *t*-test (IBM-SPSS 1.0.0.781) was used for the comparison ($p < 0.05$) of the results.

Results and Discussion

LAB and yeast Yeast numbers of *A* were between 1.2×10^3 and 3×10^3 CFU/g, while LAB were between 1.6×10^9 and 4×10^9 CFU/g. The *A* was produced using multi-stage spontaneous fermentation. More than 50 species of LAB, especially belonging to the genus *Lactobacillus*, and more than 20 species of yeasts, mostly belonging to the genera *Saccharomyces* and *Candida*, have been found in sourdough for making traditional leavened bakery products (Minervini *et al.*, 2012; Lattanzi *et al.*, 2013). These data are consistent with another study which showed dominating microorganisms in spontaneously fermented doughs. The homofermentative *Lactobacillus* and *Pediococcus* have been found both in wheat and rye sourdoughs at a level of $3 \times 10^8 - 3 \times 10^9$ CFU/g (Tulbek, 2006).

Optimization The *V* and *AV* determined based on the experimental design are also given in Table 1. There were no differences among the runs of 1, 2, 7, 9 and 13 in terms of factor levels as five replicates were set for CCD in this study. Although the results for the responses were close to each other, they were different. The difference among the similar runs (1, 2, 7, 9 and 13) and the results of other runs has indicated that

Table 1. The V and AV obtained from the experimental design

No	Amount of usage (g)		Responses	
	A	B	V (cm ³)	AV
1	49.99	4.66	1190	85.40
2	49.99	4.66	1225	80.25
3	49.99	9.33	1335	84.00
4	99.98	4.66	1280	81.25
5	49.99	0.00	1015	72.20
6	14.64	7.96	1130	67.33
7	49.99	4.66	1210	81.40
8	0.00	4.66	1010	61.30
9	49.99	4.66	1150	91.16
10	14.64	1.37	1010	70.20
11	85.34	1.37	1190	77.00
12	85.34	7.96	1345	89.25
13	49.99	4.66	1185	87.80

A; chickpea sourdough, B; baking powder, V; volume, AV; acceptability value

Fig. 1. Response surface plot showing the mutual effect of the amount of chickpea sourdough (A) and baking powder (B) on Volume (V) and Acceptability Values (AV)**Table 2.** Statistical parameters of optimization; *p* values for model selection and lack of fit tests; Model and independent variable factors (a), R² and Corrected R² for quadratic function (b)

<i>p</i> values*			
		V (cm ³)	AV
Model selection and lack of fit test	Quadratic	0.2758	0.0041
	Linear	< 0.0001	0.0322
	Lack of fit	0.3424	0.9175
Model and independent variable factors	Model	< 0.0001	0.0017
	A	< 0.0001	0.0005
	B	< 0.0001	0.0444
(a)			
		V (cm ³)	AV
R ²		0.93	0.91
Corrected R ²		0.91	0.84
(b)			

**p* < 0.05 was considered statistically significant, V; volume, AV; acceptability value, A; chickpea sourdough, B; baking powder

the model of this study is non-linear.

The data were analyzed by the software in order to determine which functions would be suggested. "Sequential model sum of squares" and "lack of fit" tests were carried out (Table 2) for the V and AV. Standard deviation, R² (R-squared) and adjusted R² were determined for each function. The values were compared, and the suggested function was ascertained.

Quadratic function in terms of V and linear function in terms of AV was approved (*p* < 0.05). Lack of fit was identified as insignificant for both properties (*p* > 0.05). When the effects of independent factors on the V and AV were taken into account (Table 2), the influences of chickpea sourdough and baking powder use in terms of cake V and AV emerged as statistically significant (*p* < 0.05). Additionally, the model was also determined to be statistically significant (*p* < 0.05). The final equation with factors was coded (A representing chickpea

sourdough and B representing baking powder) as it follows:

$$V = +1108.62 + 72.84*A + 68.28*B \quad \dots\dots\text{Eq. 2}$$

$$AV = +80.78 + 7.86*A + 3.16*B + 2.13*A*B - 1.83*A^2 - 3.74*B^2 \quad \dots\dots\text{Eq. 3}$$

The purpose of optimization is to determine accurate values for parameters which will help to obtain the desired response. The numerical optimization was used in this study. The V and AV were evaluated together, and the first solution was selected from the three solutions offered by the software. According to the solution, amounts of use 64.02 g for A, 5.97 g for B were offered for obtaining 1249.74 cm³ V and 88.37 AV values.

Figure 1 shows the response to the interaction for the level of the A and B. The V value increases in line with the levels of the A with B. Furthermore, the AV increases in line with the

Table 3. Comparison of optimum point verification test results with the estimated values from the model

Response	Estimated value	Average experimental result*	Difference	<i>p</i> -value**
V (cm ³)	1249.74	1283.33±15.28	34.00	0.060
AV	88.37	90.67±1.53	1.53	0.121

* Mean ± standard deviation; ** $p < 0.05$ was considered statistically significant
V; volume, AV; acceptability value.

Fig. 2. Pore structure images obtained by Image Pro Plus software of cake samples (OC; optimized cake, CC; control cake)

level of the A and B. However, the AV exhibits a tendency to decrease after the central point of increase of these independent variables. The insignificant internal interaction between the level of the A and B can be seen through the circular curves at the bottom of the second graph in Figure 1.

Experimental validation of optimization results Following optimization, the levels of usage were determined as 64.02 g for A and 5.97 g for B. The cake was produced using optimized amounts in three replicates. The V and AV values of OC were determined, and the mean value was calculated. The presence of any statistically significant ($p < 0.05$) difference between the mean value and the estimated values from the model was investigated using the one sample t-test. The one sample t-test results for each response are given shown in Table 3. There wasn't found any statistically significant difference ($p > 0.05$) between the results obtained from the validation tests and the estimated values of the V or AV. This indicates that the model obtained by optimization was also experimentally successful.

Properties of cake samples (OC and CC) The cake samples OC and CC were compared in terms of various physicochemical and sensory properties.

Pore structure The pore structure of samples were examined by the image analysis (Figure 2), which revealed that while the OC had 989 pores per unit area, the CC had 894

pores. The pore number of per unit area increased with the use of chickpea sourdough. The increase in pore numbers per unit area was the result of the formation of smaller pores in OC.

The total pore numbers for the first three classes were 953 for the OC and 853 for the CC samples. In addition, whereas the total number of large pores in Class 4 and Class 5 was 36 (3.6 %) for the OC, it was only 41 (4.59 %) for the CC (Figure 3). Only B was responsible for leavening and pore formation of texture for the CC sample, whereas A and B were together responsible for the OC sample. In other words, the biological and the chemical leavening reactions that occurred in the OC sample were much more pronounced. The microbiota of A contains homo and heterofermentative LAB (Sıkılı, 2003). The heterofermentative strains can produce CO₂ in addition to the other metabolites. The pore number of per unit area in the OC samples was therefore higher than that in the CC.

Physicochemical properties The pH and TTA of chickpea sourdough in the dough stage were 4.33 and 10.40, respectively. While the usage of A caused significant reduction in cake pH, it caused an increase in TTA ($p < 0.05$)(Table 4).

The B generally have alkaline or neutral profile due to their mix contained the different chemicals such as NaOH. For that reason the cake batters have able to slightly alkaline profile generally like CC sample. Since the CC samples were produced

Fig. 3. Distribution of pore numbers according to image analysis (OC; optimized cake, CC; control cake)

Table 4. Properties of cake samples

Properties	OC	CC	<i>p</i> -value**
pH	7.30 ± 0.05	8.37 ± 0.06	0.001
TTA	1.55 ± 0.052	0.65 ± 0.049	0.001
Volume (cm ³)	1283.33 ± 15.28	1260 ± 3.50	0.118
Specific volume (cm ³ /g)	2.23 ± 0.02	2.39 ± 0.03	0.005
Crust thickness (mm)	1.85 ± 0.39	0.98 ± 0.16	0.061
Crust			
<i>L</i> *	42.75 ± 1.12	45.83 ± 2.38	0.013
<i>a</i> *	17.84 ± 0.34	16.53 ± 0.27	0.022
<i>b</i> *	23.07 ± 2.73	24.91 ± 2.85	0.363
Crumb			
<i>L</i> *	72.89 ± 1.89	71.43 ± 1.08	0.313
<i>a</i> *	-1.60 ± 0.12	-1.96 ± 0.13	0.035
<i>b</i> *	26.55 ± 1.18	24.73 ± 0.59	0.116
Inhibition (%)	29.65 ± 1.4	11.83 ± 1.6	0.002

Mean ± standard deviation, ***p* < 0.05 was considered statistically significant, OC; optimized cake, CC; control cake, TTA; total titratable acidity

by using B only, the pH was higher than that in the OC, and the TTA was lower. On the other hand, the sourdough has quite acidic profile (approx pH 4.5). In this study, when the sourdough added to cake batter, the cake has gained neutral profile (or in other words more acidic than CC sample). The acidic composition of the A together with the alkaline profile of B caused more neutral profile in the OC samples. The studies about the microbiota of A have shown that it contains microorganisms such as *Enterococcus* spp., *Lactobacillus* spp., *Streptococcus* spp., *Enterococcus* spp., *Pediococcus* spp. and *Saccharomyces cerevisiae* (Sikili, 2003). The LAB synthesize

lactic acid by homofermentation of hexoses and synthesize lactic acid, acetic acid, ethanol and CO₂ by heterofermentation of hexoses. A reduction in pH causes an increase in the protease activity of cereals. Additionally, the LAB also have their own enzyme activity. The increasing in enzyme activity raises the free amino acid content by hydrolyzing proteins (Hansen and Schieberle, 2005), therefore it may lead resulting higher TTA value. In a study that used three heterofermentative (*L. sanfrancisco*, *L. brevis*, *L. fermentum*) and two homofermentative LAB (*L. delbrueckii*, *L. plantarum*), Hansen *et al.* (1989) determined that TTA was increased by the

Fig. 4. Moisture loss during shelf life of the cake samples (OC, optimized cake; CC, control cake)

heterofermentative LAB.

The crust thickness of OC was found significantly higher than the CC ($p < 0.05$). Although, the volume increased in the OC by the usage of A because the weight of OC was higher, the specific volume was found lower than the CC. Moreover, while the difference between the volumes of the samples wasn't found statistically significant ($p > 0.05$), the difference between the specific volumes was found significant ($p < 0.05$). While only B used in CC sample was responsible for the gas production, the B as chemically and the heterofermentative LAB as biologically produced CO_2 and provided pore structure in the OC. The enhancing effects of the A on the cake's volume may have been due to various factors. The gluten structure in acidic doughs that contain sourdough has a better gas retention capacity (Gobbetti *et al.*, 1995). This is caused by the solubility of pentosans during the sourdough process (Corsetti *et al.*, 2000) and by the increase in endogenous enzyme activities through lower pH related to the use of sourdough (Clarke *et al.*, 2003). The use of the A resulted in the positive effects on volume and specific volume. The pore structure analysis revealed a higher pore number per unit area in the OC samples.

According to the color measurements for the cake crust, L^* value decreased and a^* value increased significantly ($p < 0.05$) by the usage of the A, although any change was not obtained in the b^* value ($p > 0.05$) (Table 4). During the baking stage in the oven, the water vapor moves from crumb to crust, particularly in the "oven rise" stage. The water carries fats/oils emulsified with it toward the cake crust. While the vapor leaves the structure, the oil stays on the surface during the baking process. The moisture analysis showed that the water was retained in the crumb structure. This may have been promoted by the thicker crust formation in the OC samples. In other words, less oil/fat transfer dependent on water vapor occurred for the CC samples. It is likely that the lower L^* value in the crust is related to this phenomenon.

The color measurement results showed that a^* value increased in the cake crumb by the use of A ($p < 0.05$) (Table 4). It caused a rise in a^* values not only in the cake's crumb, but also in the cake's crust. The color is one of the most important factors affecting the consumer's preferences for the bakery products. The formation of the yellow-gold-brown colors often described as browning, is due to non-enzymatic chemical reactions specifically the Maillard and caramelization reactions produce colored compounds during the baking process (Artan *et al.*, 2010). When the bakery products containing reducing sugars and amino groups are heated, the caramelization and the Maillard reaction may take place simultaneously (Purlis and Salvadori, 2009). The participation in chemical browning reactions of the simple sugars produced at the end of the sourdough fermentation may have resulted in an increase in the a^* value of the crust in particular. A decrease in pH during fermentation positively affects the browning reactions, probably because the Amadori rearrangement requires H^+ . The duration of the fermentation has been reported to influence the color of the bakery product through the formation of the various compounds as precursors of brown pigments (Martinez Anaya, 1996).

The moisture contents were 33.08 % and 28.98 % for the OC and CC samples, respectively (Figure 4). The reduction of the moisture was lower for the OC samples during storage possibly corresponding a facilitated moisture retention by the usage of chickpea sourdough. For bakery products such as cake, not only high initial moisture, but also moisture retention during shelf life is important. The retrogradation process known as staling is also related to moisture loss. Additionally, the exopolysaccharide production of LAB has been thought to play a role in moisture retention (Galle and Arendt, 2014). The conversion of starch into simple sugars as a result of fermentation may also affect moisture retention. The crust thickness was greater in the OC samples than in the CC. The

Fig. 5. Sensory characteristics of the cake samples indicated with radar graphs (OC, optimized cake; CC, control cake)

thick crust that formed may have led to moisture retention inside the crumb. The gas retention capacity of gluten is known to increase in acidic dough (Gobbetti *et al.*, 1995) and the modification of gluten caused by chemical reactions and biological action of microorganisms may together have a function for the retention of moisture in the cake structure.

DPPH radical scavenging activity DPPH radical inhibition (%) value of OC sample was significantly ($p < 0.05$) higher than the CC's value (Table 4). The results obtained in this study shown that the usage of A enhanced the antioxidant activity of the cake. The antioxidant activity of the baked goods are affected by the various factors and the phytochemicals mainly alter in during processes such as fermentation. The increase in antioxidant activity resulting from sourdough fermentation can be explained by different biochemical and metabolic events. The metabolisms of LAB in sourdough facilitate lipid oxidation during fermentation. It is known that homofermentative lactobacillus increase the lipid oxidation (Vermeulen *et al.*, 2007). The formation or modification of the bioactive compounds during sourdough's fermentation can improve the antioxidant activity of the cake. Several studies shown that some LAB were capable of releasing antioxidant peptides during sourdough fermentation (Rizzello *et al.*, 2012). In a study conducted by Coda *et al.* (2012), it was ascertained that some selected LAB produced antioxidative peptides during sourdough fermentation. When acidity increases, it is expected an increase in the total phenolic content and a decrease in tiamin, ferulic acid dehydromers, tocopherols and tocotrienols (Hansen *et al.*, 2002). However, the mechanism of these changes in bioactive component levels during sourdough fermentation has not yet been explained.

Sensory profile The radar graphs (Figure 5) clearly showed the difference of sensory profiles between the cake samples.

Oil and egg aromatic profiles in cake are not preferable by consumers. The use of the A led to less perception of fat and

egg aromatic profiles in the OC samples. A more malty character was found in the CC than in OC samples. The panelists also reported that acidic and sweetish characters were more dominant in the OC than the CC sample. Although the A was a kind of the sourdough type, it gave sweet flavor/aroma to the cake sample. This reason may be that, the starch/simple sugar conversions occurred during chickpea sourdough fermentation. Moreover, the chickpea sourdough is also known as "sweet yeast. The different flavor and aroma compounds (especially carbonyl compounds such as propionaldehyde, n-butyl aldehyde, ethyl butyl ketone), and some organic acids (such as acetic acid, propionic acid, valeric acid, crotonic acid) form in the bakery products which contain the A. This effect depended on the microbiota of A and their metabolites. Therefore, the products used A gains characteristic flavor and sweet taste (Özkaya, 1992; Sikili, 2003). Fermentation of sugars by microbiota leads to a large number of volatile compounds that are responsible for the distinctive characteristics associated with the flavor of bakery products. Moreover, effects of sourdough on flavor are based on three main factors: i) formation of acidity, ii) formation of flavor precursors such as amino acids and iii) formation of volatile compounds (Tulbek, 2006). The acidic flavor in the OC samples may result from the organic acids produced by the LAB during the fermentation process. The impact on the flavor depends on acidity level, level of free amino acids and important flavor compounds in sourdough. The formation of acidity has a profound effect on flavor. Furthermore high amount of free amino acids in sourdough has been linked to an enhanced intensity of the overall flavor of bakery products. (Martinez Anaya, 1996). It was determined that The OC samples exhibited higher scores in terms of overall taste/flavor characteristics.

Furthermore some panelist evaluated that while the OC sample was more sweet, the CC sample was more fatty. Because the basic formulation were same in both sample OC

and CC, this fact make thought that the evaluation of panelists about taste of the samples were completely sensorial.

Conclusion

The use of the A with B in the cake, improved the pore structure and physicochemical properties, and enriched the sensory profile, in this study. It also improved the crust color of the cake as well as its volume and its pore structure. Following optimization, the levels were 64.02 g for the chickpea sourdough and 5.97 g for the baking powder, while the control sample contained 9.33 g of baking powder. The results suggest that the A could be applicable for other chemically leavened bakery products. Moreover, it could be used as a natural ingredient, as a partial replacement for the baking powder. The traditional A production method used in this study was a typical multistage fermentation, which combines a soaking stage and lactic acid fermentation. This may have had the potential to reduce antinutrient factors and to improve bioavailability. Therefore the bioavailability of proteins, minerals and other nutritional properties can be examined in future studies. If the traditional A production can be adopted for the industrial level, it can serve as an alternative for the satisfaction of the today's consumer's demands towards additive free, functional bakery products. According to the findings of this study, further detailed exploration of the beneficial and potential health improving properties of the A is now required.

References

- Akgün, N.A. and Doymaz, I. (2005). Modelling of olive cake thin-layer drying process. *J. Food Eng.*, **68**, 455–461.
- Artan, M.Y., Karim, R., Chern, B.H., Ariffin, A.A., Man, Y.C., and Chin, N.L. (2010). The influence of different formulation of palm oil /Palm stearin –based shortenings on the quality of white bread. *Middle-East J. Sci. Res.*, **5**, 469–476.
- Bianchia, F., Careria, M., Chiavaro, B.E., Muscia, M., and Vittadini, B.E. (2008). Gas chromatographic–mass spectrometric characterisation of the Italian Protected Designation of Origin “Altamura” bread volatile profile. *Food Chem.*, **110**, 787–793.
- Clarke, C.I., Schober, T.J., Angst, E., and Arendt, E.K. (2003). Use of response surface methodology to investigate the effects of processing conditions on sourdough wheat bread quality. *Eur. Food Res. Technol.*, **217**, 23–33.
- Coda, R., Rizzello, C.G., Pinto, D., and Gobbetti, M. (2012). Selected lactic acid bacteria synthesize antioxidant peptides during sourdough fermentation of cereal flours. *Appl. Environ. Microbiol.*, **78**, 1087–1096.
- Coda, R., Melama, L., Rizzello, C.G., Curiel, J.A., Sibakov, J., Holopainen, U., Pulkkinen, M., and Sozer, N. (2015). Effect of air classification and fermentation by *Lactobacillus plantarum* VTT E-133328 on faba bean (*Vicia faba* L.) flour nutritional properties. *Int. J. Food Microbiol.*, **193**, 34–42.
- Corsetti, A., Gobbetti, B., De Marco, B., Balestrieri, F., Paoletti, F., and Rossi, J. (2000). Combined effect of sourdough lactic acid bacteria and additives on bread firmness and staling. *J. Agri. Food Chem.*, **48**, 3044–3051.
- Curiel, J.A., Coda, R., Centomani, I., Summo, C., Gobbetti, M., Rizzello, C.G. (2015). Exploitation of the nutritional and functional characteristics of traditional Italian legumes: The potential of sourdough fermentation. *Int. J. Food Microbiol.*, **196**, 51–61.
- De Angelis, M., Rizzello, C.G., Alfonsi, G., Arnault, P., Cappelle, S., Di Cagno, R., Gobbetti, M. (2007). Use of sourdough lactobacilli and oat fibre to decrease the glycaemic index of white wheat bread. *Br. J. Nutr.*, **98**, 1196–1205.
- De Angelis, M., Damiano, N., Rizzello, C.G., Cassone, A., Di Cagno, R., Gobbetti, M. (2009). Sourdough fermentation as a tool for the manufacture of low-glycemic index white wheat bread enriched in dietary fibre. *Eur. Food Res. Technol.*, **229**, 593–601.
- Galle, S. and Arendt, E.K. (2014). Exopolysaccharides from sourdough lactic acid bacteria A review. *Crit. Rev. Food Sci. Nutr.*, **54**, 891–901.
- Gobbetti, M., Corsetti, A., and Rossi, J. (1995). Interaction between lactic acid bacteria and yeasts in sourdough using a rheofermentometer. *World J. Microbiol. Biotechnol.*, **11**, 625–630.
- Gobbetti, M., Rizzello, C.G., Di Cagno, R., and De Angelis, M. (2014). How the sourdough may affect the functional features of leavened baked goods. *Food Microbiol.*, **37**, 30–40.
- Gomez, M., Olete, B., Rosell, C.M., Pando, V., and Fernandez, E. (2008). Studies on cake quality made of wheat-chickpea flour blends. *Food Sci. Technol.*, **41**, 1701–1709.
- Hansen, A., Lund, B., and Lewis, M.J. (1989). Flavour of sourdough rye bread crumb. *Food Sci. Technol.*, **22**, 141–144.
- Hansen, A. and Schieberle, P. (2005). Generation of aroma compounds during sourdough fermentation: Applied and fundamental aspects. *Trends Food Sci. Technol.*, **16**, 85–94.
- Hera, E., Ruiz-París, E., Olete, B., and Gómez, M. (2012). Studies of the quality of cakes made with wheat-lentil composite flours. *Food Sci. Technol.*, **49**, 48–54.
- Jukanti, A.K., Gaur, P.M., Gowda, C.L.L., and Chibbar, R.N. (2012). Nutritional quality and health benefits of chickpea (*Cicer arietinum* L): A Review. *Br. J. Nutr.*, **108**, 11–26.
- Kadam, M.L., Salve, R.V., Mehrajfatema, Z.M., and More, S.G. (2012). Development and evaluation of composite flour for Missi roti/chapati. *J. Food Process. Technol.*, **3**:134. doi:10.4172/2157-7110.1000134.
- Karamac, M., Amarowicz, R., Weidne, S., Abe, S., and Shahidi, F. (2002). Antioxidant activity of rye caryopses and embryos extracts. *Czech. J. Food Sci.*, **20**, 209–214.
- Kefalas, P., Kotzamanidis, S., Sabanis, D., Yupsani, A., Kefala, L.A., Kokkalis, A., and Yupsanis, T. (2009). Bread making of durum wheat with chickpea sourdough or compressed baker's yeast. *J. Food Qual.*, **32**, 644–668.
- Lappi, J., Selinheimo, E., Schwab, U., Katina, K., Lehtinen, P., Mykkänen, H., Kolehmainen, M., Poutanen, K. (2010). Sourdough fermentation of wholemeal wheat bread increases solubility of arabinoxylan and protein and decreases postprandial glucose and

- insulin responses. *J. Cereal Sci.*, **51**, 152–158.
- Lattanzi, A., Minervini, F., Di Cagno, R., Diviccaro, A., Antonielli, L., Cardinali, G., Cappelle, S., Angelis M.D., and Gobbetti, M. (2013). The lactic acid bacteria and yeast microbiota of eighteen sourdoughs used for the manufacture of traditional Italian sweet leavened baked goods. *Int. J. Food Microbiol.*, **163**, 71–79.
- Lönnér, C., Welander, T., Malin, N., and Dostalek, M. (1986). The microflora in a sourdough started spontaneously on typical swedish rye meal. *Food Microbiol.*, **3**, 3–12.
- Maioli, M., Pes, G.M., Sanna, M., Cherchi, S., Dettori, M., Manca, E., Farris, G.A. (2008). Sourdough-leavened bread improves postprandial glucose and insulin plasma levels in subjects with impaired glucose tolerance. *Acta Diabetol.*, **45**, 91–96.
- Martinez Anaya M.A. (1996). Enzymes and bread flavor. *J Agric Food Chem.*, **44**, 2470–2480.
- Minervini, F., Di Cagno, R., Lattanzi, A., De Angelis, M., Antonielli, L., Cardinali, G., Cappelle, S., and Gobbetti, M. (2012). Lactic acid bacterium and yeast microbiotas of 19 sourdoughs used for traditional/typical Italian breads: interactions between ingredients and microbial species diversity. *Appl. Environ. Microbiol.*, **78**, 1251–1264.
- Najjar, A.M., Parsons, P.M., Duncan, A.M., Robinson, L.E., Yada, R.Y., Graham, T.E. (2009). The acute impact of ingestion of breads of varying composition on blood glucose, insulin and incretins following first and second meals. *Br. J. Nutr.*, **101**, 391–398.
- Ndife, J., Abdulraheem, L.O., and Zakari, U.M. (2011). Evaluation of the nutritional and sensory quality of functional breads produced from whole wheat and soy a bean flour blends. *African J. Food Sci.*, **5**, 466–472.
- Olapade, A. and Adetuyi, D.O. (2007). Comparison of different methods of producing Bambara (*Voandzeia subterranean L Thou*) flours for preparation of ‘moin-moin’ *Niger. Food J.*, **25**, 150–157.
- Pasqualone, A., Caponio, F., Summo, C., and Arapi, V. (2004). Characterisation of traditional Albanian breads derived from different cereals. *Eur. Food Res. Technol.*, **219**, 48–51.
- Poinot, P., Arvisenet, G., Ggrua-Priol, J., Colas, D., Fillonneau, C., Le Bail, A., and Prost, C. (2008). Influence of formulation and process on the aromatic profile and physical characteristics of bread. *J. Cereal Sci.*, **48**, 686–697.
- Purlis, E. and Salvadori, V.O. (2009). Modelling the browning of bread during baking. *Food Res. Int.*, **42**, 865–870.
- Rizzello, C.G., Coda, R., Mazzacane, F., Minervini, D., and Gobbetti, M. (2012) Micronized by-products from debranned durum wheat and sourdough fermentation enhanced the nutritional, textural and sensory features of bread. *Food Res. Int.*, **46**, 304–313.
- Rizzello, C.G., Calasso, M., Campanella, D., Angelis, M.D., and Gobbetti, M. (2014a). Use of sourdough fermentation and mixture of wheat, chickpea, lentil and bean flours for enhancing the nutritional, texture and sensory characteristics of white bread. *Int J. Food Microbiol.*, **180**, 78–87.
- Rizzello, C.G., Curiel, J.A., Nionelli, L., Vincentini, O., Cagno, R.D., Silano, M., and Coda, R. (2014b). Use of fungal proteases and selected sourdough lactic acid bacteria for making wheat bread with an intermediate content of gluten. *Food Microbiol.*, **37**, 59–68 .
- Rizzello, C.G., Montemurro, M., and Lorusso, A. (2016) Use of sourdough made with quinoa (*Chenopodium quinoa*) flour and autochthonous selected lactic acid bacteria for enhancing the nutritional, textural and sensory features of white bread. *Food Microbiol.*, **56**, 1–13.
- Roy, F., Boye, J.I., and Simpson, B.K. (2010). Bioactive proteins and peptides in pulse crops: Pea, chickpea and lentil. *Food Res. Int.*, **43**, 432–442.
- Sikili, Ö.H. (2003) Nohut mayasının mikrobiyolojik ve lezzet karakteristiklerinin araştırılması (PhD Thesis) Ege University, İzmir, Turkey (in Turkish).
- Simsek, Ö., Çon, A.H., and Tulumluoğlu, Ş. (2006). Isolating lactic starter cultures with antimicrobial activity for sourdough processes. *Food Control.*, **17**, 263–270.
- Sudha, M.L., Baskaran, V., and Leelavathi, K. (2007). Apple pomace as a source of dietary fiber and polyphenols and its effect on the rheological characteristics and cake making. *Food Chem.*, **104**, 686–692.
- Torrieri, E., Pepe, O., Ventorino, V., Masi, P., and Cavella, S. (2014). Effect of sourdough at different concentrations on quality and shelf life of bread. *LWT - Food Sci. Technol.*, **56**, 508–516.
- Tulbek, M.C.(2006). Development and characterization of fermented Chickpea in bread making, (PhD Thesis), North Dakota State University, Fargo, North Dakota, p 152.
- Volpini-Rapina, L.F., Sokei, F.R., and Conti-Silva, A.C. (2012). Sensory profile and preference mapping of orange cakes with addition of prebiotics inulin and oligofructose. *LWT - Food Sci. Technol.*, **48**, 37–42.