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DEVELOPMENT OF BREAD WITH NaCl REDUCTION AND CALCIUM FORTIFICATION: STUDY OF ITS QUALITY CHARACTERISTICS

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ABSTRACT

The impact of NaCl reduction and replacement by $CaCl_2 : CaCO_3$ (50:50) on dough and bread characteristics is addressed in this study. Three recipes of white bread were formulated with different percentage of NaCl substitution; all doughs had 1.8 g of total salts added per 100 g flour weight basis. Comparison was performed against control bread containing 1.8 g of NaCl per 100 g flour weight basis. Alveograph and farinograph results indicated that addition of calcium decreased dough extensibility, stretchability and stability time, keeping strong flour characteristics. Calcium salts increased hardness of upper crust and decreased hardness of lower crust. An increase of calcium salts promoted lighter crumb and crust color. Descriptive sensory analysis indicated that 16 out of 25 traits showed significant differences between control and recipes. Principal component analysis using variables such as texture, color and sensory traits indicated that breads produced with 50% NaCl substitution were comparable with the control.

PRACTICAL APPLICATIONS

The current interest in promoting a healthy diet encourages the design of foods that prevent diseases and cover specific nutritional requirements. Thus, reduction of salt intake and the fortification with beneficial minerals such as calcium is pertinent, as bread constitutes an important source of salt intake and its calcium contribution is low. The results show that it is possible to maintain the organoleptic characteristics and acceptability of the bread with reduced sodium content and 50% replacement by calcium salts. Estimating bread serving of 50 g, the calcium-fortified bread with 50% sodium reduction could cover 13.5 and 17.6% of the calcium recommended daily intake for schoolchildren and adults with added beneficial effect on health, due to salt reduction. The purposed change in the sodium–calcium content has a dual beneficial effect on the health of the population, prevents problems related to high salt intake and helps to resolve calcium deficiency.

INTRODUCTION

Bread varies widely around the world, as do their production techniques. However, it has the same basic ingredients, namely, cereal flour, water, yeast or another leavening agent, and sodium chloride (Dewettinck *et al.* 2008). Bread has a notable role in the human diet. The Portuguese annual bread intake is 70 kg per capita (Quilez and Salas-Salvado

2012) similar to the mean annual bread consumption in Argentina (Ferrante *et al.* 2011).

Bread is one of the major contributors to dietary sodium intake due to its high consumption (Ni Mhurchu *et al.* 2011). Salt improves bread taste by providing the flavor of saltiness, by enhancing or masking other flavors and by controlling microbes growth. In bread, sodium chloride also contributed notably to regulation of fermentation and gluten network development (Kilcast and Angus 2007).

An intake of around 1.5 g of sodium chloride per day per person is necessary to maintain body functions, whereas the average salt intake in most countries around the world is approximately 9–12 g of salt per day per person. High sodium intake is associated with high blood pressure and an increase in the risk of cardiovascular disease (Doyle and Glass 2010). Portugal has one of the highest mortality rates from stroke in Europe, and some Portuguese studies have suggested a relationship between this fact and high sodium chloride consumption (Carrageta *et al.* 1994). In Argentina, one in each three adults has elevated blood pressure and hypertension diagnosis. Health authorities are committed to improving primary health care of hypertensive subjects and to reducing sodium chloride intake in the population. As result, in 2003 the World Health Organization called for a reduction in population salt intake to 5 g or less per day (Joint WHO-FAO Expert Consultation on Diet and the Prevention of Chronic 2003). Eleven countries in the European Union have signed up to make a 16% reduction in salt intake over the next 4 years (Doyle and Glass 2010).

Sodium chloride reduction in bread causes technological effects in dough rheology and handling, resulting in poor quality breads in terms of texture, volume, flavor and color (Farahnaky and Hill 2007). Therefore, researchers have focused on the development of sodium chloride substitutes (Gyu-Hee 2011; Kaur *et al.* 2011), such as potassium. This mineral has physiologic advantages but presents off-flavors at high levels, such as metallic or bitter taste (Morris *et al.* 2010). In addition, it seems that there is no single compound that can replace the salt flavor in bread (Doyle and Glass 2010). Partial replacements of sodium by calcium and magnesium salts have been described without adverse effects on dough rheology (Kilcast and Angus 2007; Kaur *et al.* 2011).

Furthermore, adequate calcium intake is important both for building peak bone mass in the first three decades of life and for attenuating loss of bone in later years. An adequate calcium intake also has protective effects against hypertension and colorectal cancer (Jorde and Bonaa 2000; Hambly *et al.* 2002). However, previous studies have demonstrated that calcium intake by people in Argentina is less than adequate (Bassett *et al.* 2011), which can contribute to an increased risk of developing osteoporosis. Calcium chloride is a good source of calcium and a good fortifying agent. It is one of the 10 compounds demonstrated by the Food and Drug Administration as safe and lawful to use as a dietary supplement (Eledah 2005). Fortification of foods such as orange juice, carbonated beverages, yeast breads and breakfast cereals has been used to improve calcium intake (Romanchik-Cerpovicz and McKemie 2007).

In this sense, the development of low-cost food highly consumed by the majority of the population, such as bread, with low salt content and calcium fortification, while keeping its sensorial characteristics would be a successful achievement from both technological and nutritional point of view. Therefore, the main objective of this study was to develop white bread with lower sodium chloride levels and higher calcium content, and to investigate whether it maintains quality traits that guarantee its acceptability by consumers.

MATERIALS AND METHODS

Raw Materials

Commercial wheat flour type 65 was used. Dry yeast was obtained from FALA (Lesaffre Ibérica S.A., Valladolid, Spain). The product was obtained by multiplication of cells from a pure culture of yeast species *Saccharomyces cerevisiae* especially selected. The salt substitute mixture was elaborated with NaCl, $CaCO_3$ and $CaCl_2$ from Sigma-Aldrich, Co. (Steinheim, Germany).

Bread Balls Development

The wheat bread balls of this study were produced at pilot scale in an experimental laboratory (CERES, Porto, Portugal) presenting a mixer, fermentation chambers and ovens (Sopaco, Rio Tinto, Portugal). Standard control dough containing NaCl (1.8 g per 100 g flour weight basis) was prepared (Table 1). Experimental wheat bread formulation included 1.5 kg of wheat flour, 0.9 kg of water (v/w, flour basis), 27 g of salt (w/w, flour basis), 30 g of dry yeast (w/w, flour basis) and 15 g of dough improver (w/w flour basis). A total of $n = 8$ recipes of bread were initially elaborated, and three of them (Table 1) were finally chosen for being further

TABLE 1. ADDITION OF SODIUM AND CALCIUM SALTS TO WHEAT FLOUR IN CONTROL, A, B AND C BREAD RECIPES

	Salts addition to wheat flour							
	mg/100 g of flour				g/1.5 kg of flour			
Ingredients	Control	A	B	C	Control	A	B	C
NaCl	1,800	360	540	900	27	5.40	8.10	13.5
$CaCO_3$	0	720	630	450	0	10.8	9.45	6.75
$CaCl_2$	0	720	630	450	0	10.8	9.45	6.75

analyzed according to results on a preliminary acceptability analysis (results not shown). $CaCl_2$ and $CaCO_3$ (50:50) was mixed with different levels of NaCl for preparing recipes, namely, A, B and C, which contained different percentage of NaCl substitution (80, 70 and 50, respectively). All dough had 1.8 g of total salt ($NaCl + CaCl_2 + CaCO_3$) per 100 g flour weight basis. The ingredients were incorporated in a bowl of spiral mixer and kneaded for 20 min. The dough was manually molded into approximate 80 g of balls and rested in a fermentation chamber at 37C and 80% relative humidity for 60 min. After fermentation, the dough was baked in an oven at 223C for 20 min and left to cool. Four batches of bread were made based on 1.5 kg of flour that yields 2.5 kg of dough, to obtain 20 breads (CERES).

Chemical Characterization of Wheat Flour Mixed with Salts

The chemical characteristics of mixtures containing wheat flour and salts were determined according to the methods from the International Association for Cereal Science and Technology (ICC): moisture (ICC STANDARD 101/1 1976), wet gluten content and gluten deformation index (ICC STANDARD 106/2 1984), protein content (ICC STANDARD 105/2 1994), ash content (ICC STANDARD 104/1 1990), falling number (ICC STANDARD 107/1 1995). Analyses were performed in triplicate.

Dough Rheology Analysis

The alveograph (model NG, Chopin, Tripette et Renaud, Villeneuve-la-Garenne, France) was used to measure dough height, CO_2 production and loss, allowing the calculation of the retention capabilities following the international standard ISO 5530-4 (1991) at the CERES laboratory. The following factors were analyzed: maximum overpressure needed to blow the dough bubble (P), which expresses dough resistance; average abscise at dough bubble rupture (L), which means dough extensibility; the index of swelling (G); the alveograph ratio (P/L); and deformation energy (W), representing the energy necessary to inflate the dough bubble to the point of rupture. The alveograph characteristics were automatically recorded by the Alveolink-NG computer software program (Chopin, Tripette et Renaud).

The promylograph (model T6-SIFA06, Labortechnik Egger, Wasserburg, Germany) was used to determine the characteristics of dough during mixing. The farinograms were obtained using the constant flour weight procedure of the standard ICC methods 115/1 and carried out according to the recommendations of the manual device. All measurements were made at room temperature (25C). The parameters evaluated were water absorption (WA), which indicates the percentage of water required to yield a dough consistency of 500 Brabender units (BU); dough development time (DDT), which is the highest point of the curve time to reach maximum consistency; dough stability (S), the time during dough consistency keeps at 500 BU; elasticity and extensibility (EE), the bandwidth at the highest point of the curve; softening of dough (SD), the difference in units between the line of the consistency and the medium line of the top curve 12 min after development time. All dough experiments were performed in triplicate.

Determination of Bread Sodium and Calcium Content

The sodium content of the breads was analyzed by flame photometry (model PFP7, JenWay, Essex, U.K.) with filters for sodium, according to methodology validate for bread by Vieira *et al.* (2012). Determination of calcium content of breads was performed by flame atomic absorption spectrometry (model 3100, Perkin Elmer, Überlingen, Germany).

Texture of Bread

Texture analysis was performed in a texture analyzer (model TA-XT-2iHR, Stable MicroSystems, Ltd., Surrey, U.K.) containing 5 kg of load cell. Calibrations were carried out with 2 kg of load cell. Data were analyzed using Exponent Software supplied along with the instrument. Upper and lower crusts of bread balls ($n = 6$) were subjected to a penetration depth of 30 mm through a two-cycle sequence using a spherical probe (25 mm in diameter) (Cyl. Perspex P/25, Stable MicroSystems, Ltd.) at a cross head speed of 1 mm/s. Storage time was standardized; thus, samples were tested 6 h after removal from the oven and packaged in open paper bags containing five bread balls each. The following texture parameters were extracted from the measured force deformation curves: hardness (N) = maximum force required to compress the sample (peak force during the first compression cycle); springiness (dimensionless) = height that the sample recovers during the time that elapses between the end of the first compression and the start of the second; cohesiveness (dimensionless) = extent to which the sample could be deformed before rupture (A1/A2, A1 being the total energy required for the first compression and A2 the total energy required for the second compression); chewiness (N) = the work needed to chew a solid sample to a steady state of swallowing (hardness × cohesiveness × springiness).

Color Measurement

Instrumental color was measured across the crumb and the upper and lower crust of the bread balls ($n = 6$). The following color coordinates were determined: lightness (L^*), redness (a^*) and yellowness (b^*). Color parameters were determined using a colorimeter (model CR-300, Minolta, Ramsey, NJ) with illuminate D65, a 0° standard observer and a 2.5 cm port/viewing area. The colorimeter was standardized before use with a white tile having the following values: $L^* = 93.5$, $a^* = 1.0$ and $b^* = 0.8$.

Sensory Analysis

Descriptive analysis was conducted by a trained panel (12 members) to evaluate the sensory characteristics of bread samples. The sensory evaluation was conducted using a 1–7 unstructured scale, with 1 representing the lowest intensity and 7 the highest intensity, for all attributes. The sensory panel was composed of master students from the University of Porto who had sensory analysis in their curriculum and expressed an interest and disposition to undertake the work. Panelists were trained for descriptive analysis according to the guidelines in the ISO 8586 (2012) using control and other bread samples in four 2-h sessions for term optimization and calibration for accuracy in interpretation and repeatability. Thus, before tasting the samples, screening and training were carried out in order to distinguish the different percentages of NaCl substituted with $CaCO_3$ and $CaCl_2$ (50:50) at different levels.

In session 1, various attributes, partly from the Portuguese norm ISO 5492 (2008) and from literature (Kihlberg *et al.* 2006), were suggested to start the panel training. Panelists tasted control bread samples with specific highlighted appearance, flavor and texture attributes. Panelists were invited to generate terms to describe personal observations. Odor was defined as the olfactory sensation felt directly by the nose (orthonasal). Aroma was defined as the olfactory sensation felt in the retronasal passage upon mastication. In session 2, redundant descriptive terms were removed, and samples exhibiting specific attributes were tested to be included on ballots. Session 3 was designed to establish ballot anchors where all attributes and their synonyms were fitted on an unstructured scale (7 points). To assist panelists, terms were used to describe each attribute at low intensity (score 1) and high intensity (score 7). In session 4, the ballots were tested by panelists in individual booths with unknown representative samples. The panel agreed unanimously on 26 attributes to constitute the descriptive profile for the breads (Table 2). Collected data were analyzed by analysis of variance (ANOVA), and panelists' deviations were assessed to determine where additional training was needed. In evaluation sessions, samples including control and other bread samples were labeled with random three-digit codes. In each session, panelists received a maximum of five samples to evaluate. The experimental samples were served to panelists in random order, and two evaluation sessions were performed.

Statistical Analysis

The effect of salt substitution was analyzed by one-way ANOVA. When a significant effect ($P < 0.05$) was detected, paired comparisons between means were conducted using the Tukey's test. Principal component analysis (PCA) was applied to evaluate the relationships between the studied parameters. Analyses were performed using the IBM SPSS Advanced Statistics 20.0 (IBM Software Group, Chicago, IL).

RESULTS AND DISCUSSION

Characterization of Flour and Salt Mixtures

Chemical characteristics of the control, A, B and C wheat flour mixed with sodium and calcium salts were assayed through evaluation of wet gluten, dry gluten, falling number, ash, protein and moisture. Wet gluten ranged between 24.1 and 24.9%, dry gluten ranged between 9.3 and 9.7%, falling number ranged between 292.5 and 310.4 s, ash content was 2.4%, protein content ranged between 8.3 and 8.6%, and moisture ranged between 13.6 and 13.9%. No statistical differences ($P < 0.05$) were found in any of these parameters in the four formulations, and all of them were in concordance with the legislated parameters of flour T65 as stated in the Portuguese legislation (Portaria no. 425 1998)

Dough Rheology Evaluation

Table 3 exposes the results of the alveograph and farinograph analysis of the control and NaCl reduction of dough used in this study (A, B and C). No significant differences were observed in maximum overpressure needed to blow the dough bubble (P), which varied from 78.9 to 82.0 mmHg, nor on the values for curve configuration ratio (P/L) between the dough produced with different percentages of salt substitutes. Strong gluten flour will have high *P* values and is preferred for breads. Higher value for *P* indicates that the dough resists deformation and is elastic in nature (Indrani *et al.* 2007).

The addition of calcium salts to dough significantly ($P < 0.05$) affected dough extensibility (L), the index of swelling (G) and the deformation energy (W), which was higher in the control than in the experimental batches. In addition, the values of these characteristics tended to decrease as the proportion of sodium chloride substitution increased. Thus, it can be observed that dough C, with 50% of salt substitution, was the most similar sample when

TABLE 2. ATTRIBUTES USED FOR SENSORY EVALUATION OF BREAD BALLS BY QUANTITATIVE–DESCRIPTIVE TEST

Sensory attributes	Definitions
Appearance	
Crust color intensity	Degree of color darkness in the crust ranging from light to dark brown
Crumb color intensity	Degree of color darkness in the crumb ranging from white to dark brown
Porosity	The extent of perforation of the bread surface
Crumb cell homogeneity	Homogeneity of the size of the crumb cells
Visual dryness	Aspect of bread surface
Odor attributes	
Fermented	Characteristic aroma of fermented dough
Wheat	Aroma typical of whole meal flour of wheat mixed with boiled water in proportion 1:2
Cereals	Aroma typical of cereals (oats, rye, grain) mixed with boiling water in proportion 1:3
Toasted	The odor impression of bread and crumb after baking/heating
Odor secondary	Other odors perceived
Overall odor	Degree of perceived intensity of overall odor of the sample
Aroma	
Yeasty	The flavor associated with natural yeast as leaving agent
Cereals flavor	Taste typical of cereals (oats, rye, grain) mixed with boiling water in proportion 1:3
Toasted (crust)	The aroma associated with roasted/burnt wheat products
Aroma secondary	Other aromas perceived
Sweetness	Having or denoting the characteristic taste of sugar. Standard solution: sucrose 16 g/L
Saltiness	Perception of salinity. Standard solution: sodium chloride 5 g/L
Sourness	Sharp biting taste like the taste of vinegar or lemons. Standard solution: citric acid 1 g/L
Astringent	The feeling factor causing a dry, puckering sensation on the oral surfaces; associated with tannins
Bitter	Fundamental taste sensation of which caffeine or quinine are typical. Perceived by the back of the tongue and characterized by solutions of quinine, caffeine and other alkaloids; usually caused by over-roasting. Standard solution: caffeine 0.5 g/L
Aftertaste intensity	Flavor staying after tasting
Texture	
By touch	
Crumb firmness	Resistance to the crumb pressure on the finger
Crumb elasticity	Ability of the sample to return to the starting position after compression
Mouthfeel	
Adhesiveness	Analysis after compression between the tongue and the palate. Degree to which the product adheres to the palate.
Cohesiveness	The extent to which a material can be deformed before it ruptures

Adapted from Kihlberg *et al.* 2006.
Assessors: $n = 12$, scale 1 = low, 7 = high.

compared with the control. It has been described that high *L* values exhibited high extensibility and easy stretchability of dough into a thin film, and that high values for W result in bigger dough bubbles, owing to balanced elastic and extensibility properties (Indrani *et al.* 2007).

The farinograph characteristics of the control and experimental dough are also presented in Table 3. The WA values ranged from 56.8 to 58.3 g/100 g, and no significant differences were observed between dough. This parameter is related to the volume of water needed for the distribution of dough materials, their hydration and the gluten network development (Mohammed *et al.* 2012). Regarding DDT required for the dough to reach 500 BU of consistency, it was not modified by substitution with calcium salts, and the results showed a time development of 120 s for all doughs. The tolerance to overmixing was determined by dough stability (S) and by the decrease in consistency over a given time. Higher time stability was observed in control and C samples (7 and 6 min, respectively) in comparison with the A and B batches. The stability time decreased in white bread balls with the increase of sodium chloride replacement. In general, the stability value is an index of dough strength, with higher values indicating stronger dough (Mohammed *et al.* 2012).

Concerning the EE of dough, there were no significant differences between all dough formulated, varying from 113 to 120. When the EE of the dough is high, there is an increased possibility for a greater bread volume. Dough softening degree (SD) was statistically ($P < 0.05$) different between dough, with the control batch showing lower values than the experimental bread samples. The lowest SD value was recorded for control dough, and the addition of calcium salts had an increasing effect on the degree of softening. However, between the dough with calcium salts there

TABLE 3. CHARACTERISTICS OF WHEAT DOUGH SAMPLES

Samples/Parameters	Control	A	B	C
P (mmHg)	82.0 ± 2.3	80.5 ± 2.9	78.9 ± 4.0	79.2 ± 6.0
L (mm)	105.0 ± 2.3b	81.5 ± 6.3a	85.8 ± 2.6a	89.0 ± 4.8a
G (mL)	22.8 ± 0.3b	20.1 ± 0.7a	20.6 ± 0.3a	21.0 ± 0.6a
W (10^{-4}J)	245.3 ± 5.6b	199.6 ± 2.3a	202.4 ± 9.4a	209.2 ± 13.4a
P/L	0.8 ± 0.0	1.0 ± 0.1	0.9 ± 0.1	0.9 ± 0.1
WA (g/100g)	56.8 ± 0.7	58.3 ± 1.3	57.4 ± 0.3	57.6 ± 0.4
DDT (s)	120.0 ± 0.0	120.0 ± 0.0	120.0 ± 0.0	120.0 ± 0.0
S (s)	445.0 ± 31.2b	305.0 ± 37.7a	280.0 ± 34.6a	350.0 ± 45.8a,b
EE	120.0 ± 0.0	113.3 ± 11.5	120.0 ± 0.0	120.0 ± 0.0
SD	103.3 ± 15.3a	156.7 ± 15.3b	170.0 ± 10.0b	143.3 ± 15.3b

A, B and C bread with 80, 70 and 50% of NaCl replacement with CaC_{l2} and $CaCO_3$, respectively. Values with different letter in the same parameter are significantly different ($P < 0.05$). Data shown are the obtained mean values of triplicates ± standard deviation from each type of dough. Control, bread without NaCl replacement; DDT, dough development time; EE, elasticity and extensibility; G, the index of swelling; L, dough extensibility; P, dough tenacity; P/L, alveograph ratio; S, dough stability; SD, softening of the dough; W, deformation energy of dough; WA, water absorption.

were no significant differences. A small degree of softening has been related to strong flours with long development time and high stability (Mohammed *et al.* 2012).

Both alveograph and farinograph results approved the strong flour characteristic with a large proving tolerance for the three experimental recipes. These results are in agreement with those described by Kaur *et al.* (2011), which concluded that sodium chloride can be replaced by other salts without having any adverse effect on dough rheology. Moreover, the C recipe seems to be the most appropriate in technological terms of quality as well as the most proximate to the control samples in the alveograph and farinograph characteristics.

Bread Evaluation

Concerning sodium content per serving of baked bread (50 g), the control bread presented higher sodium content (262 mg) than the A, B and C experimental batches, 62.5, 102 and 140 mg, respectively. The four bread groups presented significantly different sodium content ($P < 0.05$), and levels found in the analyzed samples were in compliance with Portuguese Legislation that establishes a limit lower than 550 mg of sodium/100 g bread (Lei no. 75 2009). Concerning calcium content per serving of baked bread (50 g), the control bread presented lower calcium content (62.5 mg) than the A, B and C experimental batches, 278, 242 and 176 mg, respectively.

Texture parameters of upper and lower crusts of bread balls in this study are exposed in Table 4. Crust statistical differences were found in hardness ($P < 0.01$) and cohesiveness ($P < 0.001$). Control and C bread balls showed higher values for hardness than A and B. For cohesiveness, batch A had higher values than the rest of the bread balls. With respect to the upper crust, all texture parameters showed significant differences. Lower springiness and higher hardness, cohesiveness and chewiness were found in A bread balls in comparison with the rest of batches. These findings point out the effect of NaCl substitution with calcium salts on bread texture, especially when there is 80% of NaCl replacement, whereas a lower influence was observed with 70 and 50% of sodium chloride replacement. Comparable results have been found in other studies. Bread loaves containing 1.2, 0.6 and 0.3% of NaCl did not show differences in hardness (Lynch *et al.* 2009). In gluten-free bread, Krupa-Kozak *et al.* (2011) found softer and more elastic crumbs in calcium-fortified breads than in unfortified ones. It can also be observed that 80% NaCl replacement has different influence on the lower and upper crust, leading to softer lower crust and harder upper crust.

Table 4 also shows L^*, a^* and b^* color parameters in upper and lower crusts and crumb of the bread balls analyzed in the present work. In the lower crust, L^*, a^* and b^* showed lower values in C and the control group than in A and B. In the upper crust, a^* and b^* were significantly ($P < 0.001$) higher in A than in C and control bread balls, whereas B showed the lowest values for these two color parameters. In the crumb the effect of NaCl replacement was also found in the three studied color parameters, although it only led to significant differences ($P \leq 0.001$) between groups in a^* and b^*. Thus, higher a^* values were obtained in C and control than in A and B bread balls, whereas B and C had higher b^* values than A and control groups. These results clearly show the influence of NaCl replacement on color parameters of the crust, with light-colored crust when substituting 70 and 80% of NaCl with

TABLE 4. TEXTURE AND COLOR PARAMETERS OF BREAD BALLS CRUMB AND CRUST

		Control	A	B	C	*P*
Texture						
Lower crust	Hardness (N)	13.57 ± 2.25a	11.52 ± 1.43ab	10.55 ± 0.61b	13.54 ± 1.90a	0.01
	Cohesiveness	1.57 ± 0.12b	1.82 ± 0.18a	1.53 ± 0.06b	1.63 ± 0.12ab	0.004
	Springiness	0.82 ± 0.02	0.82 ± 0.04	0.83 ± 0.02	0.81 ± 0.03	0.851
	Chewiness (N)	14.51 ± 2.52	15.73 ± 2.15	13.82 ± 0.83	16.66 ± 1.07	0.055
Upper crust	Hardness (N)	8.78 ± 0.13c	11.55 ± 0.44a	9.67 ± 0.68b	10.18 ± 0.55b	<0.001
	Cohesiveness	1.78 ± 0.10b	2.29 ± 0.34a	1.83 ± 0.08b	1.92 ± 0.15b	0.001
	Springiness	0.83 ± 0.03a	0.79 ± 0.02b	0.83 ± 0.03a	0.83 ± 0.02a	0.027
	Chewiness (N)	12.84 ± 0.43c	25.72 ± 2.74a	14.27 ± 0.55bc	15.55 ± 0.85bc	<0.001
Color						
Lower crust	*L**	34.34 ± 1.33d	48.79 ± 2.50a	42.25 ± 2.27b	29.55 ± 4.06c	<0.001
	*a**	12.72 ± 0.46b	14.60 ± 1.13a	15.11 ± 1.22a	10.30 ± 0.33c	<0.001
	*b**	18.30 ± 0.71b	29.94 ± 2.51a	26.80 ± 2.23a	19.45 ± 4.04b	<0.001
Upper crust	*L**	63.52 ± 6.45	66.07 ± 5.76	64.15 ± 6.34	62.12 ± 5.18	0.716
	*a**	5.18 ± 0.44b	7.80 ± 1.47a	2.08 ± 0.44c	6.93 ± 0.80b	<0.001
	*b**	25.80 ± 2.29ab	29.15 ± 1.35a	20.73 ± 2.14c	24.64 ± 1.97ab	<0.001
Crumb	*L**	71.08 ± 1.56	71.27 ± 2.45	74.63 ± 4.16	74.92 ± 1.87	0.003
	*a**	–0.68 ± 0.20b	–1.03 ± 0.22a	–1.13 ± 0.09a	–0.57 ± 0.15b	<0.001
	*b**	12.51 ± 0.64b	12.92 ± 0.94b	13.33 ± 0.61ab	14.36 ± 0.59a	0.001

Data shown are mean values of triplicate analyses ± standard deviation from each type of bread. Values with different letter in the same line are significantly different $P < 0.05$ (Tukey's test).
A, B and C bread with 80, 70 and 50% of NaCl replacement with $CaCl_2$ and $CaCO_3$, respectively.
Control, bread without NaCl replacement.

calcium salts, which could be perceived as unappealing, whereas the darkening of crust observed in the 50% NaCl replacement and control bread balls maybe presumed as beneficial and desirable (Krupa-Kozak *et al.* 2011). Concerning the influence on color characteristics of the crumb, the lower lightness in the crust of substituted NaCl bread could be related to the presence of insoluble calcium carbonate that would have been present in the dough as a white particle (Charlton *et al.* 2007). It can also be related to the Maillard browning reactions, as calcium binds weakly to Maillard reaction products. Similarly to these results, Charlton *et al.* (2007) found lighter crumb and crust color in brown bread with partial replacement of NaCl with potassium, magnesium and calcium salts, and in gluten-free bread, Krupa-Kozak *et al.* (2011) also found lower L^* values when adding calcium salts.

Figure 1 shows the mean scores of the quantitative–descriptive sensory analyses of bread balls with different

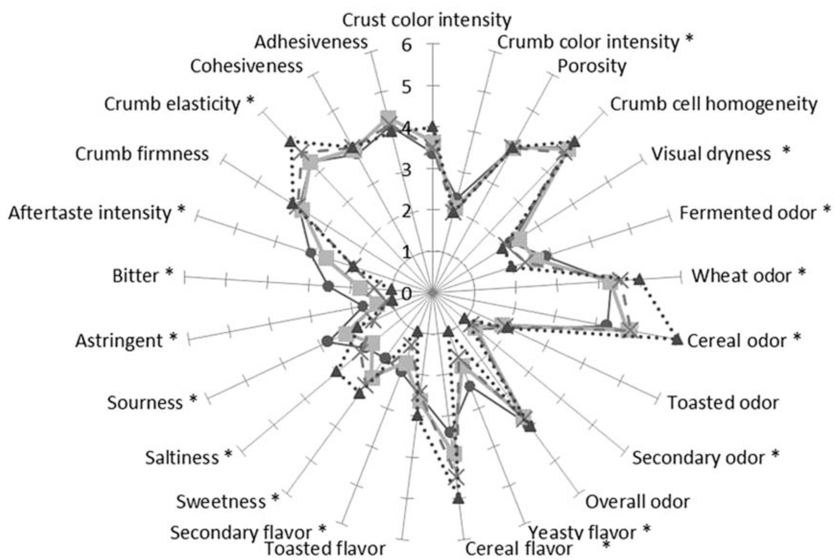

FIG. 1. GRAPHIC PRESENTATION OF QUANTITATIVE–DESCRIPTIVE SENSORY ANALYSES OF BREAD BALLS
Breads A, B and C with 80 (●), 70 (■) and 50% (×) of NaCl replacement with $CaCl_2$ and $CaCO_3$, respectively. Bread control without NaCl replacement (▲). *indicates significant effect ($P < 0.05$).

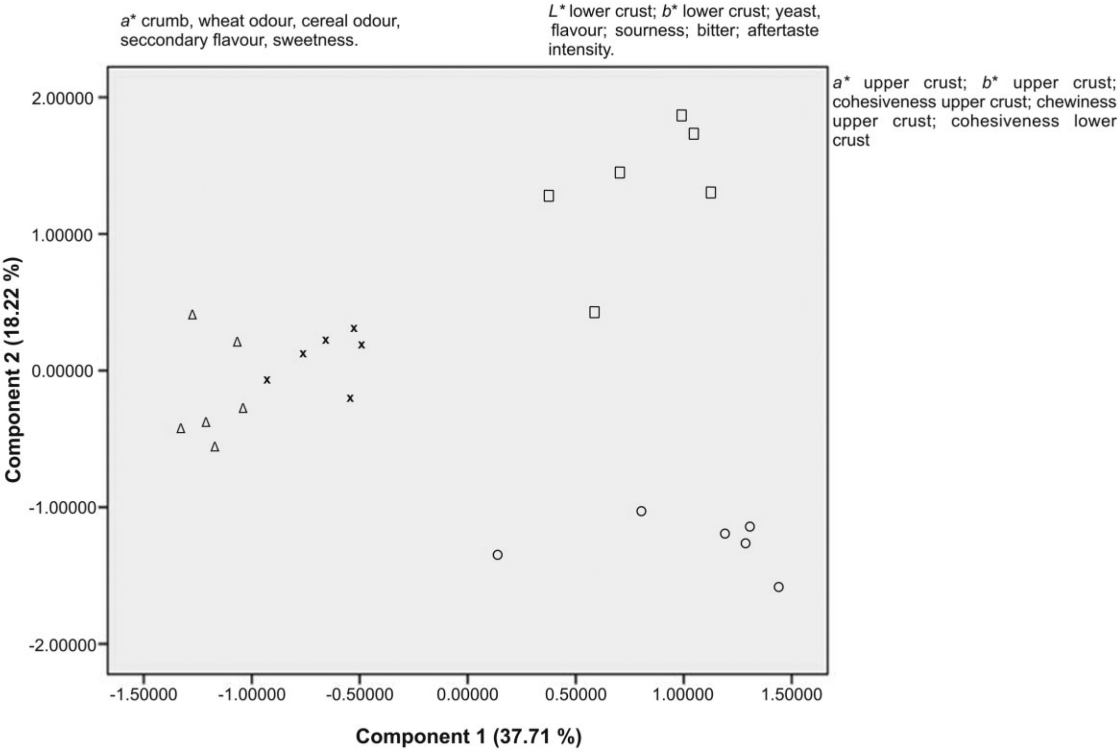

FIG. 2. SCORE PLOT OF PRINCIPAL COMPONENT ANALYSIS USING TEXTURE, COLOR AND SENSORY PARAMETERS AS VARIABLES
Breads A, B and C with 80 (○), 70 (□) and 50% (×) of NaCl replacement with $CaCl_2$ and $CaCO_3$, respectively. Bread control without NaCl replacement (Δ).

percentages of substituted salt. In relation to appearance attributes, crumb color intensity showed significant ($P \leq 0.001$) higher values in the A group than in the other batches, which could be related to the higher a^* and b^* values in this batch, and visual dryness was lower in the control and C bread balls in comparison with the A and B. Most odor and flavor sensory traits were also statistically ($P < 0.05$) different between the studied batches. The control and C groups obtained lower scores for fermented and secondary odor, secondary flavor, sweetness, sourness, astringent, bitter and aftertaste, and higher scores for wheat odor and cereal flavor than A and B breads. In fact, some of the characteristics of calcium chloride are bitterness, sourness and sweetness (Lawless *et al.* 2004). Moreover, the control group showed higher values for cereal odor and saltiness and lower values for yeast flavor than the experimental batches. Among texture attributes, only elasticity was statistically ($P < 0.05$) different, with higher values in the control batch in comparison with A, B and C. So that, 16 out of the 25 sensory traits showed significant ($P < 0.05$) differences between batches, most of them being comparable in control and C groups and different from A and B ones, indicating that panelists considered both control and C bread balls to have similar sensory characteristics, which points out the suitability of manufacturing bread with 50% NaCl substitution with calcium salts. This is in agreement with other studies concerning sensory analysis of bread with NaCl reduction (Lynch *et al.* 2009) and calcium fortification (Krupa-Kozak *et al.* 2011).

Figure 2 shows the score plot of the A, B, C and control bread balls from the PCA of the texture, color and sensory traits showing significant differences. The similarity map of the measured parameters was defined by two principal components (1 and 2), accounting for 37.71 and 18.22%, respectively, of the total variance. The a^* crumb, wheat odor, cereal odor, secondary flavor and sweetness showed high negative values for component 1, whereas L^* lower crust, b^* lower crust, yeast flavor, sourness, bitter and aftertaste intensity featured high positive values for component 1. For component 2, a^* upper crust, b^* upper crust, cohesiveness upper crust and cohesiveness lower crust had high positive values. In addition, the four types of bread balls were projected on different plane areas of the PC space: Samples A were located in the right lower region and B in the right upper area, whereas C and control bread were found in the middle of the left section. These results confirm the similarity in quality traits between C and control batches, whereas A and B breads differ. Thus, the suitability for manufacturing commercial bread with 50% NaCl replacement with $CaCO_3$ and $CaCl_2$ maintaining quality traits was demonstrated. Until now, other studies have achieved the development of bread with a one-quarter (Girgis *et al.* 2003) and a 32.3% (Charlton *et al.* 2007) reduction of sodium without influencing baking qualities, appearance, texture and taste. No studies have been performed with a comparably high sodium reduction while keeping sensory characteristics.

CONCLUSIONS

This study shows that it is technologically possible to produce bread with 80% NaCl replacement with calcium salts. However, in terms of quality, it is suitable to reduce 50% NaCl for maintaining dough rheology parameters and bread quality characteristics. These studies at pilot scale indicate that industrial production of these breads is acceptable by consumers. Estimating a bread serving of 50 g, the calcium-fortified bread with 50% sodium reduction could cover 13.5 and 17.6% of the calcium recommended daily intake for schoolchildren and adults with added beneficial effect on health, due to salt reduction. The future research will focus particularly on the bioavailability of calcium from these breads.

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