The effect of substitution of NaCl with KCl on chemical composition and functional properties of low-moisture Mozzarella cheese

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ABSTRACT
The effect of NaCl substitution with KCl on chemical composition, organic acids profile, soluble calcium, and functionality of low-moisture Mozzarella cheese (LMMC) was investigated. Functionality (meltability and browning), organic acids profile, and chemical composition were determined. Chemical composition showed no significant difference between experimental cheeses at same storage period, and same salt treatment. Meltability of LMMC salted with 3NaCl:1KCl, 1NaCl:1KCl, and 1NaCl:3KCl was higher compared with only NaCl (control). The amount of soluble Ca and P increased significantly during storage, with no significant difference between salt treatments. Organic acids profile did not differ between salt treatments at the same storage time.

Key words: NaCl substitution, chemical composition, functional property, low-moisture Mozzarella cheese

INTRODUCTION
Salt (NaCl) is traditionally used as a preservative and is added to cheeses to control bacterial growth and enzyme activity, and to improve flavor (Guinee and Fox, 2004; Doyle and Glass, 2010). However, an increased level of NaCl in foods leads to health problems (Fitzgerald and Buckley, 1985). The recommended daily intake for sodium is 2.4 g, equivalent to 110 mmol of Na or 6.0 g of NaCl (Kaplan, 2000); the daily sodium intake in developed countries is 10 to 35 times higher than the recommended daily intake (Dillon, 1987). Salt contributes to hypertension, which in turn, causes cardiovascular disease. Positive correlations between salt and osteoporosis (Heaney, 2006) and kidney stones have been reported. Salt content in cheeses varies from 0.7% in Swiss-type cheese to about 8% in brined cheeses (Sihufe et al., 2003; Massey, 2005; Heaney, 2006). The World Health Organization has recommended that food manufacturers reduce the salt content in their products (World Health Organization, 2007). Dairy products, especially cheese, contribute 11 to 20% of total sodium intake (Guinee, 2004a,b; Tamime, 2006). Therefore, there is increased interest worldwide in producing cheeses with low sodium content (Demott, 1985; McMahon, 2010). However, when salt concentration in cheeses is reduced, proteolysis, water activity, acidity, and bitterness increase, firmness decreases (Katsiari et al., 1998), and irregular fermentation occurs (Johnson et al., 2009). Accordingly, substitution of NaCl with other salts has been considered as an alternative technique to reduce sodium in cheeses. Potassium chloride (KCl) has been recognized as a potential salt to substitute NaCl (Petik, 1987). A mixture of NaCl and KCl has been successfully used in various cheeses without any adverse effects on cheese quality (Reddy and Marth, 1991), including Halloumi cheese (Ayyash and Shah, 2010), Kefalograviera cheese (Katsiari et al., 1997, 2000), and Cheddar cheese (Katsiari et al., 2001); however, no information is available on low-moisture Mozzarella cheese (LMMC). Low-moisture Mozzarella cheese is one of the most popular cheeses in the world used for pizza manufacturing. Production of LMMC has been increasing rapidly over the last 2 decades (Kindstedt, 2002; Kindstedt et al., 2004). Hence, producing low-salt LMMC will be in line with worldwide demands to reduce salt in food. The aim of this study was to examine the effect of NaCl substitution with KCl on chemical composition, organic acids profile, and functional properties of LMMC.

MATERIALS AND METHODS
Cheese Making
Full-fat (3% fat) homogenized and pasteurized bovine milk was purchased from a local dairy plant (Melbourne, Victoria, Australia). Low-moisture Mozzarella cheese was manufactured according to Feeney et al. (2001) with some modifications (Figure 1). Forty liters of milk was tempered to 40°C and inoculated with TCC-4 direct-in-vat starter culture (Chr. Hansen, Bayswater, Victoria, Australia) consisting of Streptococcus thermophilus and Lactobacillus delbrueckii ssp.
bulgaricus, which was added according to the manufacturer’s instructions. After 40 min, chymosin (Chr. Hansen) diluted (1:20) with distilled water was added according to the manufacturer’s instructions, and milk coagulated in 35 min. Curd was cut to 1-cm cubes and cooked at 40°C with a continuous agitation for 15 min. Whey was drained and manually pressed to release additional whey from the curd. The curd waschedared and milled until the pH of the slabs reached 5.3 to 5.2. The milled curd was dry-salted at 46 g/kg using 4 combinations of NaCl and KCl: NaCl only (A; control), 3NaCl:1KCl (B), 1NaCl:1KCl (C), and 1NaCl:3KCl (D) and allowed to mellow for 20 min. The salted curd was plasticized in 4% brine solutions (A, B, C, and D) at 80°C for 5 min. The plasticized curd was molded in circular molds (~2.5 kg per block). Cheese blocks were kept in a refrigerator until the block temperature reached 15°C. The larger circular blocks were cut radially into small blocks (500 g per block) and then each block was vacuum-packaged into barrier bags using a Multivac A300/16 machine (Multivac Sepp Haggenmuller KG, Wolfertschwenden, Germany) followed by storage at 4°C for 27 d. All experimental cheeses were made in triplicate.

Sampling

Samples of LMMC from all salt treatments were taken at 0, 9, 18, and 27 d of storage. The whole (500 g) block was wiped with a paper towel and shredded, and then subsamples were taken for the following analyses.

Chemical Composition

Moisture was determined by the oven-drying method at 102°C, protein by the Kjeldahl method, fat by the Babcock method, and ash using the muffle furnace method according to AOAC (1995). For pH measurement, grated cheese (40 g) was macerated with 40 mL of distilled water, and the pH of the resultant slurry was measured using a calibrated digital pH meter (MeterLab, Pacific Laboratory Products, Blackburn, Victoria, Australia).

Organic Acids Analysis

Lactic, citric, and acetic acids were determined using HPLC according to Ayyash and Shah (2010). Briefly, grated cheese samples (5 g) were taken from shredded cheese, blended with 25 mL of 0.009 N sulfuric acid and 70 μL of 15.5 N nitric acid, and homogenized using an Ultraturrax homogenizer (Janke & Kunkel K.G., Staufen i. Breisgau, Germany) at 20,000 rpm. After standing for 1 h in a 50°C water bath, the slurry was centrifuged for 20 min at 4,000 × g at 4°C. The soluble fraction (1.5 mL) located between the upper layer (fat) and the precipitate (casein) was further centrifuged (14,000 × g, 10 min) using a bench-top centrifuge (RT7, Sorvall, Newtown, CT). The supernatant was filtered using a 0.45-μm filter (Millex, Millipore, Bedford, MA) and aliquots of approximately 1 mL from each sample were stored in HPLC vials at −20°C until analyzed. The HPLC system consisted of a Varian 9012 solvent delivery system, a Varian 9100 auto-sampler, a Varian 9050 variable wavelength UV/visible tunable absorbance detector and a 730 data module (Varian Inc., Palo Alto, CA). An Aminex HPX-87H column (300 × 7.8 mm, Bio-Rad Laboratories, Richmond, CA), was used. Sulfuric acid (0.009 N), filtered through a 0.45-μm membrane filter (Millex, Millipore), was used as a mobile phase at a flow rate of 0.6 mL/min. The detection device was an UV-visible detector set at 220 nm with running time of 15 min.

Determination of Na, K, Ca, and P Contents by Multitype Inductively Coupled Plasma Atomic Emission Spectrometry

Contents of Na, K, Ca, and P in cheeses were determined by multitype inductively coupled plasma atomic emission spectrometry [ICPE-9000, Shimadzu Scientific Instruments (Oceania) Pty Ltd., Rydalmere, New South Wales, Australia] according to Ayyash and Shah (2010), and cheese samples were prepared according to Cortez et al. (2008). Grated cheeses (5 g) from shredded samples were digested in a mixture of HNO3 and HClO4 (5:1; Merck Pty. Ltd., Kilsyth, Victoria, Australia) on a hot plate until the digests were clear. The clear digests were filtered with a 0.45-μm filter and analyzed using the ICPE-9000. The ICPE-9000 consisted of an ASC-6100 autosampler, a hydride generator HVG-ICP, a hydrofluoric acid sample injection system HFS-2, a low-temperature thermostatic chamber NCB-1200, and the software package ICPE-9000. To calculate Na, K, Ca, and P concentrations in samples, a standard curve consisting of the 4 elements was prepared at 1, 10, 20, 30, and 40 μg/mL.

Soluble Ca and P

Soluble Ca expressed as percentage of total Ca in experimental LMMC was analyzed according to Metzger et al. (2001) with some modifications. Briefly, grated cheese (10 g) was taken from the shredded cheese lot and homogenized with 90 mL of MilliQ water (Millipex) using an Ultraturrax homogenizer (Janke & Kunkel K.G.) at 10,000 rpm for 3 min. The cheese slurry was centrifuged at 4,000 × g for 20 min and then the supernatant
Figure 1. Manufacturing and salting procedure for low-moisture Mozzarella cheese.
was filtered using a Whatman #41 filter (Whatman International Ltd., Maidstone, UK). The filtrate was refiltered with a 0.45-μm filter (Millex), and soluble Ca and P were analyzed using inductively coupled plasma atomic emission spectrometry as described above. The Ca and P percentage was calculated as follow:

\[
\text{Percentage soluble Ca or P} = \frac{\text{Soluble Ca or P (mg/100 g)}}{\text{Total Ca or P (mg/100 g)}} \times 100.
\]

**Meltability**

Meltability of LMMC was determined according to Zisu and Shah (2005) using 250-mm-long glass tubes with a diameter of 24 mm and a thickness of 3 mm (R.B. Instruments, Mt. Eliza, Victoria, Australia) with some modifications. A plunger was used to pack 15 g of finely grated cheese into the glass tubes that were sealed at one end with a rubber stopper. The other end was sealed with a perforated rubber stopper to enclose the sample. The length of the compressed cheese sample was measured by using a Vernier caliper. Tubes were placed horizontally into a forced-air oven preheated to 110°C and kept for 100 min. Cheeses were allowed to cool to room temperature (~22°C) and the length of the melted cheese was recorded. The difference in the initial and the final length was presented as the melt distance (cm), and percentage increase in melt was calculated as follows:

\[
\text{Percentage meltability} = \frac{\text{Melt distance after melting}}{\text{Initial length before melting}} \times 100.
\]

**Browning**

Browning of LMMC was determined according to Barbano et al. (1994). Ground cheese samples were weighed (20 g) into an aluminum pan (7 cm in diameter and 3 cm high) and allowed to temper at room temperature (20°C) before heating. The pans containing the samples were placed into a preheated, forced-air oven at 100°C for 1 h. Cheese samples were cooled to room temperature. Color was measured using Minolta Chroma-meter CR-300 (Minolta Corporation Ltd., Ramsey, NJ) which was calibrated before testing. Three color indices, L (light to dark), a (red to green), and b (yellow to blue) values, were taken for each sample in triplicate.

**Statistical Analysis**

One-way ANOVA was performed to investigate significant difference at level 0.05 between experimental cheeses at same storage period. Fisher’s test was carried out to examine differences between means of experimental cheeses at the same storage time (least significant difference, LSD). The significance of storage period was examined within a salt treatment using LSD. Two-way ANOVA was performed to investigate significant effect of salt treatment and storage period interaction on cheese attributes. Pearson correlations were calculated to investigate a correlation between the 4 measured minerals and other variables within the same salt treatment.

**RESULTS AND DISCUSSION**

**Chemical Composition**

The effects of substitution of NaCl with KCl at different levels on chemical composition of LMMC are presented in Table 1. Moisture, protein, fat, and ash contents did not differ significantly \((P > 0.5)\) between experimental cheeses at same storage time. This may suggest that substitution of NaCl with KCl does not have any effect on chemical composition of LMMC (Guinee, 2004b). These findings are in accordance with the results of Ayyash and Shah (2010) and Katsiari et al. (1997, 1998), who reported no significant \((P > 0.5)\) differences in chemical composition of Halloumi, Feta, and Kefalograviera cheeses, respectively. The ANOVA showed no significant difference \((P > 0.05)\) in chemical composition of experimental cheeses during storage within a salt treatment.

**Organic Acids Profile and pH Value**

Contents of lactic, acetic, and citric acids and pH values of LMMC made with the 4 salt treatments are shown in Table 2. In general, experimental LMMC did not differ significantly \((P > 0.05)\) in terms of organic acids profile or pH value. This is in agreement with the results on Halloumi cheese of Ayyash and Shah (2010). However, cheeses from treatments C and D showed higher \((P < 0.05)\) contents of lactic, citric, and acetic acids compared with those for treatments B and A. In addition, pH values of cheeses in treatments A and B were lower compared with those in C and D. This may suggest that when KCl increased and NaCl decreased in a salt treatment, the production of organic acids increased. This also agrees with results of Ayyash and Shah (2010). Although the ANOVA showed no significant \((P > 0.05)\) effect of storage period on organic acids profile and pH value, a slight decrease in pH value occurred during storage.

**Contents of Ca, P, K, and Na**

Contents of Ca, P, K, and Na in experimental LMMC made with the 4 salt treatments are presented in Figures...
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2, 3, 4, and 5, respectively. Contents of K and Na did differ \((P < 0.05)\) between experimental cheeses. This expected finding was due to the salt mixtures that were added during processing of LMMC. Similar results were found by Ayyash and Shah (2010) for Halloumi cheese. Contents of Na and K did not differ during storage within a salt treatment (Figures 4 and 5). Contents of Ca and P in experimental LMMC decreased slightly \((P > 0.05)\) during storage, with no significant differences between cheeses salted with different salt mixtures.

### Table 1. Moisture, protein, fat, and ash contents of low-moisture Mozzarella cheese made with 4 different salt treatments and stored at 4°C for 27 d

<table>
<thead>
<tr>
<th>Storage time (d)</th>
<th>Salt treatment</th>
<th>Moisture (%)</th>
<th>Protein (%)</th>
<th>Fat (%)</th>
<th>Ash (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 A</td>
<td>50.99 ± 1.59a</td>
<td>26.81 ± 0.84a</td>
<td>21.70 ± 0.99a</td>
<td>3.10 ± 0.14a</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>51.13 ± 0.60b</td>
<td>26.53 ± 1.43b</td>
<td>22.20 ± 1.19b</td>
<td>3.10 ± 0.15b</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>50.53 ± 0.86a</td>
<td>27.77 ± 0.49a</td>
<td>21.20 ± 0.44a</td>
<td>3.03 ± 0.07a</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>50.80 ± 0.84a</td>
<td>27.93 ± 0.18a</td>
<td>21.73 ± 0.89a</td>
<td>3.07 ± 0.16a</td>
<td></td>
</tr>
<tr>
<td>9 A</td>
<td>50.28 ± 0.52a</td>
<td>27.10 ± 0.35a</td>
<td>24.13 ± 0.69a</td>
<td>2.97 ± 0.11a</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>49.67 ± 0.09a</td>
<td>28.02 ± 0.69a</td>
<td>21.57 ± 0.69a</td>
<td>2.81 ± 0.04a</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>49.80 ± 0.63a</td>
<td>27.65 ± 0.32a</td>
<td>21.10 ± 0.61a</td>
<td>2.88 ± 0.04a</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>50.59 ± 0.90a</td>
<td>27.30 ± 0.22a</td>
<td>21.05 ± 1.07b</td>
<td>3.05 ± 0.14a</td>
<td></td>
</tr>
<tr>
<td>18 A</td>
<td>49.08 ± 0.21a</td>
<td>26.95 ± 0.39a</td>
<td>23.55 ± 0.26a</td>
<td>2.90 ± 0.05a</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>50.13 ± 0.49a</td>
<td>27.07 ± 0.05a</td>
<td>21.93 ± 0.72a</td>
<td>2.91 ± 0.03a</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>50.56 ± 0.45a</td>
<td>27.12 ± 0.36a</td>
<td>24.30 ± 0.95a</td>
<td>2.92 ± 0.09a</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>49.79 ± 0.69a</td>
<td>27.75 ± 0.39a</td>
<td>23.60 ± 0.70a</td>
<td>2.99 ± 0.08a</td>
<td></td>
</tr>
<tr>
<td>27 A</td>
<td>48.86 ± 0.45ab</td>
<td>26.81 ± 0.38ab</td>
<td>21.77 ± 0.43b</td>
<td>2.80 ± 0.05a</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>48.61 ± 0.16b</td>
<td>25.66 ± 0.48b</td>
<td>21.90 ± 0.45b</td>
<td>2.91 ± 0.03b</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>49.16 ± 0.71ab</td>
<td>27.13 ± 0.34a</td>
<td>23.80 ± 0.35a</td>
<td>2.80 ± 0.15a</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>50.31 ± 0.27a</td>
<td>27.17 ± 0.41b</td>
<td>22.77 ± 0.45ab</td>
<td>2.96 ± 0.02a</td>
<td></td>
</tr>
</tbody>
</table>

\(a,b\)Means in each column and at the same storage period with same letter did not differ significantly \((P > 0.05)\).

1Mean values ± SE of 3 trials.

2Salt treatments: A = NaCl only (control); B = 3NaCl:1KCl (wt/wt); C = 1NaCl:1KCl (wt/wt); D = 1NaCl:3KCl (wt/wt).

### Soluble Ca and P

The percentage of soluble Ca and P in experimental LMMC is presented in Figures 6 and 7, respectively. Soluble Ca and P percentages did not differ \((P > 0.05)\) between experimental cheeses at the same storage time (Figures 6 and 7), indicating that NaCl and KCl had similar effects on soluble Ca and P in LMMC. Within a salt treatment, soluble Ca and P levels increased \((P < 0.05)\) in all experimental cheeses during storage. This

### Table 2. Lactic, acetic, and citric acids content (mg/100 g of cheese) and pH values of low-moisture Mozzarella cheese made with 4 different salt treatments and stored at 4°C for 27 d

<table>
<thead>
<tr>
<th>Storage time (d)</th>
<th>Salt treatment</th>
<th>Lactic acid</th>
<th>Acetic acid</th>
<th>Citric acid</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 A</td>
<td>692.88 ± 24.3b</td>
<td>159.95 ± 7.4b</td>
<td>139.46 ± 2.3b</td>
<td>5.14 ± 0.02b</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>676.00 ± 27.4b</td>
<td>174.12 ± 1.5b</td>
<td>145.61 ± 2.7b</td>
<td>5.18 ± 0.04b</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>726.32 ± 12.5b</td>
<td>185.37 ± 3.0b</td>
<td>154.26 ± 2.6b</td>
<td>5.18 ± 0.03b</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>692.37 ± 23.1ab</td>
<td>173.67 ± 0.4ab</td>
<td>147.69 ± 4.5ab</td>
<td>5.24 ± 0.02a</td>
<td></td>
</tr>
<tr>
<td>9 A</td>
<td>692.66 ± 16.3b</td>
<td>174.20 ± 6.4a</td>
<td>147.22 ± 2.1a</td>
<td>5.16 ± 0.02a</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>690.99 ± 34.2b</td>
<td>177.91 ± 1.6a</td>
<td>152.18 ± 1.7a</td>
<td>5.13 ± 0.07a</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>730.05 ± 8.8a</td>
<td>180.78 ± 3.9a</td>
<td>150.70 ± 1.4a</td>
<td>5.23 ± 0.03a</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>775.44 ± 31.3a</td>
<td>185.36 ± 6.9a</td>
<td>153.99 ± 3.0a</td>
<td>5.22 ± 0.02a</td>
<td></td>
</tr>
<tr>
<td>18 A</td>
<td>801.49 ± 25.2a</td>
<td>167.35 ± 2.4a</td>
<td>156.66 ± 3.8a</td>
<td>5.12 ± 0.01a</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>732.18 ± 36.1a</td>
<td>156.80 ± 2.3a</td>
<td>152.67 ± 7.6a</td>
<td>5.21 ± 0.01a</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>832.58 ± 51.7a</td>
<td>199.15 ± 10.2a</td>
<td>159.26 ± 2.7a</td>
<td>5.20 ± 0.05a</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>775.15 ± 24.7a</td>
<td>185.21 ± 6.8ab</td>
<td>153.77 ± 7.9a</td>
<td>5.20 ± 0.01a</td>
<td></td>
</tr>
<tr>
<td>27 A</td>
<td>781.78 ± 33.1a</td>
<td>157.45 ± 17.9a</td>
<td>164.73 ± 3.4a</td>
<td>5.13 ± 0.02ab</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>675.06 ± 31.4b</td>
<td>158.12 ± 2.5a</td>
<td>165.51 ± 1.7a</td>
<td>5.12 ± 0.03ab</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>736.49 ± 20.5ab</td>
<td>163.39 ± 1.4a</td>
<td>158.84 ± 3.8a</td>
<td>5.11 ± 0.04b</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>734.68 ± 29.4ab</td>
<td>183.22 ± 4.9a</td>
<td>154.08 ± 7.3a</td>
<td>5.20 ± 0.02a</td>
<td></td>
</tr>
</tbody>
</table>

\(a–c\)Means in each column and at the same storage period with same letter did not differ significantly \((P > 0.05)\).

1Mean values ± SE of 3 trials.

2Salt treatments: A = NaCl only (control); B = 3NaCl:1KCl (wt/wt); C = 1NaCl:1KCl (wt/wt); D = 1NaCl:3KCl (wt/wt).

\(a\)\(b\)Means in each column and at the same storage period with same letter did not differ significantly \((P > 0.05)\).

1Mean values ± SE of 3 trials.

2Salt treatments: A = NaCl only (control); B = 3NaCl:1KCl (wt/wt); C = 1NaCl:1KCl (wt/wt); D = 1NaCl:3KCl (wt/wt).
is attributed to the conversion of insoluble Ca and P to soluble Ca and P during storage and is in accordance with the results of Metzger et al. (2001).

**Meltability**

Increase in meltability, measured in centimeters and as a percentage, of experimental LMMC during storage is shown in Figure 8A and B. Meltability did not differ \( (P > 0.05) \) between experimental LMMC at the same storage time. However, at the end of the storage period, LMMC in treatment A showed lower meltability compared with those in treatments B, C, and D. As shown in Figure 8, meltability increased significantly \( (P < 0.05) \) during storage within each salt treatment. This increase may be attributed to 2 factors: (1) an increase in proteolysis during storage, which increased meltability (Kindstedt et al., 2004; Upadhyay et al., 2004), and (2) an increase in the conversion of insoluble Ca to soluble Ca, which in turn reduced the strength between casein networks (Feeney et al., 2002; Guinee et al., 2002). Meltability correlated positively with an increase in soluble Ca during storage of LMMC within a salt treatment.

**Browning**

The L-values of experimental LMMC during storage are presented in Figure 9. The L-values did not differ \( (P > 0.05) \) between experimental LMMC at the same storage time. Analysis of variance showed no significant effect of salt treatment on browning. L-values increased \( (P < 0.05) \) during storage within a salt treatment; this means there was less browning at the end of stor-
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Figure 6. Soluble Ca percentage of low-moisture Mozzarella cheese salted with 4 levels of NaCl and KCl: A = NaCl only (control); B = 3NaCl:1KCl (wt/wt); C = 1NaCl:1KCl (wt/wt); D = 1NaCl:3KCl (wt/wt), during storage at 4°C for 27 d.

Figure 7. Soluble percentage P of low-moisture Mozzarella cheese salted with 4 levels of NaCl and KCl: A = NaCl only (control); B = 3NaCl:1KCl (wt/wt); C = 1NaCl:1KCl (wt/wt); D = 1NaCl:3KCl (wt/wt), during storage at 4°C for 27 d.

Figure 8. Meltability increase in centimeters (a) and in percentage (b) of low-moisture Mozzarella cheese salted with 4 levels of NaCl and KCl: A = NaCl only (control); B = 3NaCl:1KCl (wt/wt); C = 1NaCl:1KCl (wt/wt); D = 1NaCl:3KCl (wt/wt), during storage at 4°C for 27 d.

Figure 9. Lightness (L)-value of low-moisture Mozzarella cheese salted with 4 levels of NaCl and KCl: A = NaCl only (control); B = 3NaCl:1KCl (wt/wt); C = 1NaCl:1KCl (wt/wt); D = 1NaCl:3KCl (wt/wt), during storage at 4°C for 27 d.

The lightness (L)-value increased compared with that on d 0. This increase is in agreement with Osaili et al. (2010) who reported an increase in L-value of LMMC during storage. L-values correlated negatively with soluble Ca contents during storage within a salt treatment. As shown in Figure 9, LMMC of treatment A showed lower (P < 0.05) L-values during storage compared with other treatments. This may suggest that the presence of KCl reduced the amount of browning of LMMC during baking. Experimental LMMC salted with KCl (treatments C and D) showed lower phosphotungstic acid-soluble N compared with control (our unpublished data). Thus, browning should be lower in these cheeses compared with control cheeses. It has been postulated that browning correlates positively with proteolysis in cheeses (Mukherjee and Hutkins, 1994; Rudan and Barbano, 1998).
CONCLUSIONS

The substitution of NaCl with KCl (3:1, 1:1, 1:3) had similar effects on chemical composition, organic acids profile, and functional properties of LMMC. In addition, LMMC salted with 1NaCl:1KCl and 1NaCl:3KCl showed significantly higher meltability and browning of LMMC compared with control. The pH values of LMMC salted with 1NaCl:1KCl and 1NaCl:3KCl were, in general, higher than those of the control cheese. Browning of LMMC salted with only NaCl was lower than that of the other salt treatments.

REFERENCES


