Effect of Calcium Chloride on the Preparation of Low-fat Spreads from Buffalo and Cow Butter

Ahmed Mohamed Abdeldaiem1,2*, Qingzhe Jin1, Ruijie Liu1 and Xingguo Wang1
1State Key Laboratory of Food Science and Technology, Synergetic Innovation Center of Food Safety and Nutrition, School of Food Science and Technology, Jiangnan University, Wuxi 214122, Jiangsu, China; 2Department of Dairy Science, Faculty of Agriculture, Suez Canal University, Ismailia-41522, Egypt
*For correspondence: Email: wxg1002@qq.com

Received: 11 January 2014 Revised accepted: 29 March 2014

Abstract

Purpose: To investigate the effects of CaCl2 on the preparation of low-fat spreads from buffalo and cow butter

Methods: Buffalo and cow butter-based low-fat spreads (B-LFS and C-LFS) were treated with CaCl2 (0, 0.02, 0.04, 0.06, and 0.08%) at pH 5.5 and stored at 4°C. They were sampled after 3, 30, 60, and 90 days, and analysed for sensory, morphological, rheological, and melting properties using a 9-point hedonic scale, digital camera, texture analyser TA-XT 2i, Physica MCR 301 rheometer, and differential scanning calorimeter, respectively.

Results: Sensory evaluation results showed that control samples were the best of all the treatments; additionally, no phase separation was found in samples treated with 0, 0.02 or 0.04% CaCl2, but separation occurred with 0.06 and 0.08% CaCl2. Generally, hardness and viscosity of samples decreased with increasing CaCl2 concentrations; however, these parameters increased during storage. Increasing CaCl2 concentrations didn’t affect the melting profiles of the spreads, but the parameter varied for B-LFS during storage. Furthermore, the temperature range of the high melting zones of the B-LFS samples was greater than that of C-LFS samples.

Conclusion: Sensory, morphological, and rheological properties were affected by CaCl2 concentrations but there were negligible effects on the melting behaviour of the spreads.

Keywords: Buffalo butter, Cow butter, Calcium chloride Low-fat spread, Sensory, Morphology, Melting

INTRODUCTION

Consumers have become increasingly health conscious and respond to the call for a diet that contains less fat, sugar, and salt, but higher fibre. Therefore, this trend has created great challenges for food technologists. For example, low-fat products prepared with a less than 40% fat content have captured increased market interest and extensive attention of food technologists [1].

Previously, there were attempts to produce bread spreads with a high dietary value containing one-half to one-quarter of the fat contained in butter and that also retains its desired appearance, flavor, texture, and sensory characteristics [2]. Obviously, the production of low-fat spreads with an increasingly larger aqueous phase requires the use of proteins and polysaccharides as thickeners or gelling agents. The ability of biopolymers to cross-link and, at high enough concentrations, to form a tangled, interconnected molecular network in water is widely known [3].
During the development of peak bone mass, calcium intake of less than 1 g per day is associated with lower bone mineral density [4]. Nutritionally sufficient levels of calcium in the diet are strongly related to the intake of dairy products, which are the richest sources of highly bioavailable calcium [5].

Therefore, the objective of this work was to study the effects of calcium chloride on sensory, morphological, rheological, and melting properties of buffalo and cow butter-based low-fat spreads (B-LFS and C-LFS).

**EXPERIMENTAL**

**Materials**

Buffalo butter (83.48% fat, 2.91% non-fat solids, 13.61% moisture, and 0.145 peroxide value) was obtained from the Department of Dairy Science, Faculty of Agriculture, Suez Canal University (Ismailia, Egypt). Cow butter (82.68% fat, 1.75% non-fat solids, 15.57% moisture, and 0.135 peroxide value), skim milk powder, and sodium chloride (table salt) were purchased from a local market in Wuxi (Jiangsu, China). Halal gelatin (80–280 Bloom) was purchased from Gelatin & Protein Co., Ltd. (Hangzhou, China). Dimodan® HP-C-distilled monoglyceride was obtained from Danisco Co. (Shanghai, China). All other reagents and solvents were of analytical or chromatographic grade to suit analytical or chromatographic grade to suit analytical requirements.

**Preparation of buffalo and cow butter oil**

Oil preparation was performed according to Fatouh et al [6] with some modifications. Both buffalo and cow butter were melted at 50°C instead of 60°C, and the top oil layer was then decanted and filtered through glass wool. The oil was then refiltered under vacuum to obtain clear buffalo and cow butter oil.

**Preparation of B-LFS and C-LFS with different CaCl₂ concentrations**

CaCl₂ treatments (B-LFS and C-LFS treated separately) were performed according to Madsen [7] with some modifications. The treatments consisted of the following (% w/w): 40% buffalo and cow butter oil, 0.5% DIMODAN®HP-C-distilled monoglyceride, 2% halal gelatin, 1% skimmed milk powder, 1% NaCl, CaCl₂ (0, i.e., control, 0.02, 0.04, 0.06, and 0.08%), 0.1% k-sorbate, and distilled water (to 100%). The steps for the preparation of CaCl₂ treatments were as follows:

1. The ingredients of the water phase (halal gelatin, skim milk powder, NaCl, and k-sorbate) were blended together with distilled water at 70°C for 10 min using a JJ-1B Electric Blender (Changzhou Runhua Electric Appliance Co., Ltd, China).

2. The temperature of the water phase was then reduced to 40°C, and the pH was adjusted with 20% w/w citric acid to 5.5 while mixing.

3. With regard to the fat phase, a portion of the melted buffalo and cow butter oil (~5 × the weight of the emulsifier) was removed and heated to 70°C with blending until the emulsifier dissolved, which was then added back to the melted butter oil at 40°C.

4. The water phase was then slowly added to the fat phase while mixing using a homogeniser (IKA® T18 Basic Ultra-Turrax®, Germany) for 5 min at speed no. 2.

5. The mixture was then pasteurised at 75°C for 10 min in a water bath while blending.

6. The temperature of the mixture was decreased from 75 to 60°C, and then CaCl₂ chloride (20% w/w) was blended with the mixture using a homogeniser (IKA® T18 Basic Ultra-Turrax®, Germany) for 3 min at speed no. 2.

7. The mixture was then allowed to pass once through a laboratory homogeniser (model: GYB, Donghua High Pressure Homogenizer Factory, Shanghai, China) at a pressure of 17 MPa and 60°C.

8. Calcium chloride treatments were kept in sterilized plastic cups (30 g) at room temperature for 15 h and then moved to a refrigerator (4°C).

**Sensory evaluation**

The sensory evaluation tests for CaCl₂ treatments (B-LFS and C-LFS) were carried out according to Patange et al [8] using a panel of 14 judges selected from Egypt, Sudan, and Yemen. Samples of CaCl₂ treatments were approximately 30 g and presented to panelists at refrigeration temperature (4°C). The color and appearance, spreadability, body and texture, flavor, and overall acceptability of the products were rated on a 9-point scale, ranging from 1 (disliked extremely) to 9 (liked extremely). Spreadability was assessed by the panelists using a slice of bread onto which the sample was spread at 4°C.

**Trop J Pharm Res, April 2014; 13(4): 520**
Morphology evaluation

The morphology evaluation test for CaCl\(_2\) treatments (B-LFS and C-LFS) were recorded with a digital camera (Sony Camera T500, Japan).

Statistical analysis

Calcium chloride treatments (B-LFS and C-LFS) were analyzed separately, and values of different tests were expressed as mean ± standard deviation (SD). One-way analysis of variance using SPSS 16 for windows (SPSS Inc, Chicago, USA) was performed on all experimental data sets. Duncan analysis was applied to evaluate the significance of differences.

RESULTS

Effect of CaCl\(_2\) concentration on sensory and morphological properties of B-LFS and C-LFS

Sensory evaluation scores of B-LFS and C-LFS with different CaCl\(_2\) concentrations are summarized in Table 1a and b. Results of sensory evaluation tests (color and appearance, body and texture, spreadability, flavor, and overall acceptability) revealed that the acceptance of these parameters by the panelists decreased gradually with increasing CaCl\(_2\) concentrations (0, i.e., control, 0.02, 0.04, 0.06, and 0.08%). In addition, all CaCl\(_2\) treatments showed decreased defects (p < 0.05) compared with the evaluation at the beginning (3 days) of the storage period. The morphology evaluation (Figure 1) of treatments showed no separate phases in the butters at CaCl\(_2\) concentrations 0, 0.02, and 0.04%, whereas both 0.06 and 0.08% CaCl\(_2\)-treated butters separated, with the phase separation in 0.08% CaCl\(_2\) more than in 0.06% CaCl\(_2\).

FIGURE 1: Effect of different CaCl\(_2\) concentrations on the sensory evaluation of B-LFS and C-LFS

Key: E1) B-LFS with 0% CaCl\(_2\) (Control), E2) B-LFS with 0.02% CaCl\(_2\), E3) B-LFS with 0.04% CaCl\(_2\), E4) B-LFS with 0.06%CaCl\(_2\), E5) B-LFS with 0.08% CaCl\(_2\), F1) C-LFS with 0% CaCl\(_2\) (Control), F2) C-LFS with 0.02% CaCl\(_2\), F3) C-LFS with 0.04% CaCl\(_2\), F4) C-LFS with 0.06% CaCl\(_2\), F5) C-LFS with 0.08% CaCl\(_2\)
Additionally, the hardness of CaCl$_2$ significantly increased (p < 0.05) during storage. Within all treatments (0.08%) were clearly lower (p < 0.05) compared to the control samples. Moreover, the viscosity of all samples treated with CaCl$_2$ significantly increased during storage at 4°C.

Effects of CaCl$_2$ concentrations on the hardness of B-LFS and C-LFS

Effects of CaCl$_2$ concentrations on the hardness of B-LFS and C-LFS were presented in Table 3. The texture evaluation showed that the differences in hardness among all CaCl$_2$ treatments (B-LFS and C-LFS) were similar to control samples, but the hardness with 0.06 and 0.08% CaCl$_2$ were clearly lower than the control. Furthermore, within all treatments, the hardness significantly increased (p < 0.05) during storage. Additionally, the hardness of CaCl$_2$ treatments (B-LFS) was slightly higher than the C-LFS treatments.

Effects of CaCl$_2$ concentrations on the viscosity of B-LFS and C-LFS

Effects of CaCl$_2$ concentrations on the viscosity of B-LFS and C-LFS samples were reported in Table 3. The viscosity among B-LFS and C-LFS separately with levels of CaCl$_2$ (0.02%, 0.04%, and 0.06%) was not significant, except for 0.06% CaCl$_2$ with B-LFS at 3 days and 0.04% CaCl$_2$ with B-LFS and C-LFS at 60 days. In addition, CaCl$_2$ treatments (0.08%) were clearly lower (p < 0.05) compared to the control samples. Moreover, the viscosity of all samples treated with CaCl$_2$ significantly increased during storage at 4°C.
Table 1(b): Effect of CaCl₂ concentrations on sensory and morphological properties of C-LFS

| Storage (days) | CaCl₂ 0% (control) | CaCl₂ 0.02% | CaCl₂ 0.04% | CaCl₂ 0.06% | CaCl₂ 0.08% |
|---------------|---------------------|-------------|-------------|-------------|-------------|
| 3             | 8.59±0.11<sup>a</sup> | 8.43±0.1<sup>b</sup> | 8.31±0.1<sup>b</sup> | 7.46±0.08<sup>b</sup> | 6.54±0.09<sup>b</sup> |
| 15            | 8.31±0.07<sup>a</sup> | 8.38±0.13<sup>b</sup> | 8.32±0.08<sup>a</sup> | 7.37±0.2<sup>b</sup> | 6.45±0.18<sup>b</sup> |
| 30            | 8.37±0.13<sup>b</sup> | 8.35±0.07<sup>b</sup> | 8.24±0.07<sup>b</sup> | 7.26±0.08<sup>bc</sup> | 6.41±0.10<sup>b</sup> |
| 45            | 8.24±0.14<sup>b</sup> | 8.26±0.14<sup>b</sup> | 8.13±0.10<sup>a</sup> | 7.17±0.12<sup>b</sup> | 6.33±0.12<sup>b</sup> |
| 60            | 8.18±0.12<sup>a</sup> | 8.22±0.05<sup>b</sup> | 8.14±0.24<sup>a</sup> | 7.12±0.10<sup>ab</sup> | 6.21±0.10<sup>bc</sup> |
| 75            | 8.14±0.12<sup>a</sup> | 8.17±0.10<sup>b</sup> | 8.12±0.09<sup>a</sup> | 7.13±0.11<sup>b</sup> | 6.11±0.06<sup>a</sup> |
| 90            | 8.10±0.13<sup>a</sup> | 8.12±0.34<sup>a</sup> | 7.88±0.13<sup>a</sup> | 6.90±0.07<sup>a</sup> | 5.93±0.10<sup>c</sup> |

Table 2: Effect of CaCl₂ concentrations on hardness of B-LFS and C-LFS

| Storage (days) | CaCl₂ 0% (control) | CaCl₂ 0.02% | CaCl₂ 0.04% | CaCl₂ 0.06% | CaCl₂ 0.08% |
|---------------|---------------------|-------------|-------------|-------------|-------------|
| 3             | 58.31±0.39<sup>a</sup> | 52.03±0.78<sup>c</sup> | 56.02±0.50<sup>b</sup> | 37.64±0.44<sup>b</sup> | 37.33±0.59<sup>b</sup> |
| 30            | 61.42±0.30<sup>a</sup> | 53.33±0.60<sup>c</sup> | 56.36±0.61<sup>b</sup> | 38.86±0.46<sup>b</sup> | 37.95±0.61<sup>b</sup> |
| 60            | 64.39±0.50<sup>a</sup> | 56.36±0.92<sup>c</sup> | 57.77±0.83<sup>b</sup> | 43.81±0.65<sup>b</sup> | 39.41±0.57<sup>b</sup> |
| 90            | 66.46±0.45<sup>a</sup> | 61.32±0.54<sup>a</sup> | 60.12±1.11<sup>bc</sup> | 46.85±0.36<sup>a</sup> | 44.78±0.47<sup>a</sup> |

| Storage (days) | CaCl₂ 0% (control) | CaCl₂ 0.02% | CaCl₂ 0.04% | CaCl₂ 0.06% | CaCl₂ 0.08% |
|---------------|---------------------|-------------|-------------|-------------|-------------|
| 3             | 58.95±0.46<sup>a</sup> | 49.01±0.52<sup>c</sup> | 52.31±0.50<sup>b</sup> | 36.77±0.51<sup>b</sup> | 34.51±0.59<sup>b</sup> |
| 30            | 61.20±0.62<sup>a</sup> | 52.42±0.62<sup>c</sup> | 53.87±0.39<sup>b</sup> | 38.11±0.44<sup>bc</sup> | 36.63±0.61<sup>bc</sup> |
| 60            | 62.16±0.66<sup>a</sup> | 54.67±0.71<sup>bc</sup> | 54.78±0.49<sup>bc</sup> | 40.15±0.48<sup>bc</sup> | 39.99±0.86<sup>bc</sup> |
| 90            | 64.00±0.96<sup>a</sup> | 59.31±0.65<sup>bc</sup> | 57.52±0.78<sup>bc</sup> | 45.36±0.77<sup>bc</sup> | 45.12±0.47<sup>bc</sup> |

**Capital letters:** Average values with different letters are statistically significant (p < 0.05) within each row. Small letters: Average values with different letters are statistically significant (p < 0.05) within each column.

**<sup>a</sup>mean±S.D.; n = 14.**

**<sup>b</sup>mean±S.D.; n = 3.**
Table 3: Effect of CaCl₂ concentrations on the viscosity of B-LFS and C-LFS

| Storage (days) | apparent viscosity (η_{app} (Pa s) at 100 γ⁻¹)ᵃ |
|---------------|-----------------------------------------------|
|               | B-LFS                                         | C-LFS                                         |
|               | CaCl₂ 0% (control)                            | CaCl₂ 0.02%                                  | CaCl₂ 0.04%                                  | CaCl₂ 0.06%                                  | CaCl₂ 0.08%                                  |
| 3             | 0.32±0.07ᵃᵇᶜ                                  | 0.30±0.03ᵃᵇᶜ                                 | 0.29±0.03ᵃᵇᶜ                                 | 0.23±0.03ᵇᶜ                                  | 0.13±0.04ᵇᶜ                                  |
| 30            | 0.43±0.09ᵃᵇᶜ                                  | 0.43±0.05ᵃᵇᶜ                                 | 0.46±0.08ᵃᵇᶜ                                 | 0.41±0.03ᵃᵇᶜ                                 | 0.26±0.04ᵃᵇᶜ                                 |
| 60            | 0.49±0.05ᵃᵇᶜ                                  | 0.55±0.04ᵃᵇᶜ                                 | 0.58±0.05ᵃᵇᶜ                                 | 0.48±0.04ᵇᶜ                                  | 0.34±0.03ᵃᵇᶜ                                 |
| 90            | 0.60±0.08ᵃᵇᶜ                                  | 0.56±0.04ᵃᵇᶜ                                 | 0.66±0.05ᵃᵇᶜ                                 | 0.55±0.03ᵇᶜ                                  | 0.36±0.05ᵃᵇᶜ                                 |

 капитал letters: average values with different letters are statistically significant (p < 0.05) within each row. Small letters: average values with different letters are statistically significant (p < 0.05) within each column. ⁱMean ± SD; n = 3.

Figure 2: Thermograms of butter containing varying concentrations of calcium chloride

Table 4: Effect of CaCl₂ on the melting point behavior of B-LFS

| CaCl₂ (%) | Storage (days) | B-LFS Melting zone (°C) | C-LFS Melting zone (°C) |
|-----------|----------------|-------------------------|-------------------------|
|           | A   | B   | C   | D   | E   | F   | G   | H   | K   |
| 0         | 3   | -    | -0.72 | 17.14 | -   | 31.99 to 37.90 | -0.47 | 16.14 | 32.24 to 34.75 |
|           | 90  | -    | -1.22 | 13.49 | -   | 23.56 | 30.98 to 37.02 | -0.97 | 16.01 | 31.86 to 35.63 |
| 0.02      | 3   | -    | -0.48 | 16.78 | -   | 32.15 to 36.81 | -0.23 | 15.90 | 32.15 to 34.80 |
|           | 90  | -    | -0.85 | 14.37 | -   | 23.68 | 30.48 to 37.27 | -0.72 | 16.01 | 31.99 to 34.63 |
| 0.04      | 3   | -    | -0.23 | 16.91 | -   | 32.40 to 37.57 | -0.98 | 15.77 | 31.77 to 34.67 |
|           | 90  | -    | -0.85 | 15.00 | -   | 23.81 | 30.22 to 36.64 | -1.35 | 15.88 | 31.61 to 35.38 |
| 0.06      | 3   | -    | -0.48 | 16.78 | -   | 31.90 to 36.81 | -0.73 | 16.28 | 32.02 to 35.05 |
|           | 90  | -    | -0.49 | 14.63 | -   | 23.81 | 30.98 to 37.02 | -1.60 | 16.14 | 31.73 to 35.76 |
| 0.08      | 3   | -23.03 | -0.23 | 16.65 | -   | 32.15 to 37.32 | -0.48 | 15.52 | 31.90 to 34.54 |
|           | 90  | -0.85 | 15.00 | 24.06 | -   | 31.11 to 37.39 | -0.97 | 15.88 | 31.86 to 35.76 |
Effect of CaCl\textsubscript{2} concentration on thermal behavior of B-LFS and C-LFS – aaa

The thermal profiles of B-LFS and C-LFS with different CaCl\textsubscript{2} concentrations are presented in Figure 2 and Table 4. The melting zone (A) was only detected by DSC after 3 days of storage with 0.08% CaCl\textsubscript{2} (B-LFS), but disappeared after 90 days of storage. The temperatures of the major peaks (B and G) slightly decreased after 90 days, and the differences between temperatures of melting zones B and G together were slight. Moreover, the temperatures between the enthalpic peaks of D and H were similar, but after 90 days, no effects were observed on the melting zone of H. With all CaCl\textsubscript{2} treatments (B-LFS), two enthalpic peaks (C and E) were detected. Furthermore, the differences in broad shoulders (high melting zones of F and K) among and within CaCl\textsubscript{2} treatments (B-LFS and C-LFS separately) were slight. On the other hand, all temperature ranges of the melting zones for F were greater than for K.

DISCUSSION

Phase separation occurred with 0.06 and 0.08% CaCl\textsubscript{2}, as the attraction potential (Van der Waals' interaction) was greater than the repulsion potential: however, our results were consistent with those of Keowmaneechai and McClements [9], who reported that the droplet aggregation of menhaden emulsions may be due to the combined contributions of both the effects of heating on increased hydrophobic attractions and the influence of CaCl\textsubscript{2} on decreased electrostatic repulsions.

Scores for body and texture declined after CaCl\textsubscript{2} treatments (B-LFS and C-LFS) during storage due to the proteolytic action of microorganisms in the nonfat portion of the sample [8]. In addition, the changes in spreadability scores of the treatments during storage may be attributed to protein degradation and/or decreased water holding capacity by the nonfat fraction, resulting in increased softening of the spread, particularly towards the end of storage [8]. On the other hand, the decline in flavor scores during storage may be attributed to a loss of freshness [8]. The bitter flavor imparted by CaCl\textsubscript{2} treatments (B-LFS and C-LFS) appeared at higher concentrations (0.06 and 0.08%), whereas there was no bitterness detected in either 0.02 or 0.04% CaCl\textsubscript{2} when compared with the control samples.

The hardness and viscosity of CaCl\textsubscript{2} treatments were significant increasing during the storage periods, due to the slow post-crystallization processes and development of bonds within the fat crystal network that took place during storage [10].

In general, hardness and viscosity decreased with increasing CaCl\textsubscript{2} concentrations, presumably because an increase in CaCl\textsubscript{2} leads to the weakening of the gelatin, and in addition, because of the attraction and repulsion potentials (see sensory evaluation tests). Panouillé and Larreta-Garde [11] found that the high concentrations of Ca\textsuperscript{2+} in sodium caseinate emulsions could lead to an over-association of alginate chains, resulting in a weakening of the gel.

Hardness was correlated with the viscosity of CaCl\textsubscript{2} treatments (B-LFS and C-LFS) however, our results were in agreement with those observed by Glibowski et al [12], who reported that hardness was highly correlated with the viscosity of spreads. Furthermore, the solidifying points for both buffalo and cow milk fat were 16.0 – 28.0°C and 15.0 – 23.5°C, respectively [13]. In addition, Patel and Frede [14] found that the crystallization of buffalo milk fat begins at a higher temperature than does cow milk fat. Therefore, it’s clear that both solidifying points and crystallization are responsible for the hardness and viscosity test results.

An increase in CaCl\textsubscript{2} did not affect the melting profiles of B-LFS and C-LFS separately, but there were differences in the melting profiles of the B-LFS samples during storage. Furthermore, the temperature ranges of the high melting zones of the B-LFS samples were greater than in the C-LFS samples; these results suggest that a slight increase in total high melting species [15] is in total accordance with hardness and viscosity. However, the changes in the shape of the melting profile could be due to changes in polymorphism [16]. Ramamurthy and Narayan [17] reported that buffalo milk fat has a greater proportion of high melting triglycerides than does cow milk fat (9 – 12% and 5 – 6%, respectively).

CONCLUSION

Treatments with CaCl\textsubscript{2} (0.02 and 0.04%) were deemed acceptable by the panelists; whereas higher concentrations (0.06 and 0.08%) were unaccepted. Generally, hardness and viscosity of B-LFS and C-LFS separately treated with CaCl\textsubscript{2} decreased with an increase in CaCl\textsubscript{2}, but increased during storage. With regard to thermal behaviour, we did not notice changes in the
melting profiles of B-LFS and C-LFS separately with increasing CaCl₂, but we noticed differences in the melting profile of B-LFS samples during storage. In addition, the temperature ranges of the high melting zones of B-LFS were greater than in C-LFS.

ACKNOWLEDGEMENT

This work was supported by the National Key Technology Research and Development Program in the twelfth Five-year Plan of China (Contract no. 2012BAD36B06) 2011BAD02 B03/04.

REFERENCES

1. Cheng L, Lim B, Chow K, Chong S, Chang Y. Using fish gelatin and pectin to make a low-fat spread. Food hydrocolloids 2008; 22(8): 1637-1640.
2. Mageean P, Jones S. Low-fat spread products. Food Sci Technol Today 1989; 3: 162-4.
3. Ross-Murphy S. In Viscoelasticity of Biomaterials; Glasser, W, Halakeyama, H, Eds. 1992; American Chemical Society: Washington DC.
4. Weaver CM. Calcium requirements of physically active people. Am J Clin Nutr 2000; 72(2): 579s-584s.
5. Oliveri B, Parisi MS, Zeni S, Mautalen C. Mineral and bone mass changes during pregnancy and lactation. Nutrition 2004; 20(2): 235-240.
6. Fatouh A, Singh R, Koehler P, Mahran G, El-Ghandour M, Metwally A. Chemical and thermal characteristics of buffalo butter oil fractions obtained by multi-step dry fractionation. LWT-Food Sci Technol 2003; 36(9): 483-496.
7. Madsen F. Substitution of gelatin in low-fat spread: a rheological characterisation. SP Pub-Roy Soc Chem 2000; 251: 411-420.
8. Patange D, Patel A, Singh R, Patil G, Bhosle D. Storage related changes in ghee-based low-fat spread. J Food Sci Technol 2013; 50(2): 346-352.
9. Keowmaneechal E, McClements D. Influence of EDTA and citrate on thermal stability of whey protein stabilized oil-in-water emulsions containing calcium chloride. Food Res Int 2006; 39(2): 230-239.
10. Alexa RI, Mounsey JS, O'Kennedy BT, Jacquier JC. Effect of k-carrageenan on rheological properties, microstructure, texture and oxidative stability of water-in-oil spreads. LWT-Food Sci Technol 2010; 43(6): 843-848.
11. Panouillé M, Larreta-Garde V. Gelation behaviour of gelatin and alginate mixtures. Food hydrocolloids 2009; 23(4): 1074-1080.
12. Glibowski P, Zarycki P, Krzepkowska M. The rheological and instrumental textural properties of selected table fats. Int J Food Prop 2008; 11(3): 678-686.
13. Patel A, Gupta V, Singh S, Singh A. Advances in fat-rich dairy products. Centre of advanced studies, Dairy Technology Division, National Dairy Research Institute (ICAR), Karnal-132001, February 5-March 6, 2002, ed. B Bector. 2002; National Dairy Research Institute (ICAR), Karnal-132001.
14. Patel A, Frede E. Studies on thermal properties of cow and buffalo milk fats. Lebensm Wiss Technol 1991; 24(4): 323-327.
15. Aguedo M, Hanon E, Danthine S, Paquot M, Lognay G, Thomas A, Vandebol M, Thonart P, Wathelet J-P, Blecker C. Enrichment of anhydrous milk fat in polyunsaturated fatty acid residues from linseed and rapeseed oils through enzymatic interesterification. J Agric Food Chem 2008; 56(9): 1757-1765.
16. Vithanage CR, Grimson MJ, Smith BG. The effect of temperature on the rheology of butter, a spreadable blend and spreads. J Texture Stud 2009; 40(3): 346-369.
17. Ramamurthy M, Narayanan K. Fatty acid compositions of buffalo and cow milk fats by gas liquid chromatography (GLC). Milchwissenschaft 1971; 26(11): 693-696.