CARPATHIAN JOURNAL OF FOOD SCIENCE AND TECHNOLOGY

Journal homepage:**http://chimie-biologie.ubm.ro/carpathian_journal/index.html**

# CHEMICAL, RHEOLOGICAL AND SENSORY CHARACTERISTICS OF PROCESSED CHEESE SPREAD ANALOGUES

**Elsayed Mohamed Abd El-Wahed* and Mahetab F.R. Hassanien**

*Department of Food Science, Faculty of Agriculture, Zagazig University, Zagazig E-44511, Egypt.*
**abdelwahed2010@zu.edu.eg*

**Article history:**
Received:
15 May 2018
Accepted:
15 December 2018

**Keywords:**
*Processed cheese;*
*Analogue, sensory,*
*Texture;*
*Microstructure;*
*Peanut cream.*

**ABSTRACT**

The present work as undertaken to assess information on the physico-chemical composition, fatty, texture profile, microstructure and sensory evaluation of processed cheese analogue made by substituting 50% and 100% of butter fat with vegetable fat (peanut cream fat). Both the control processed cheese and the processed cheese spread analogue containing peanut cream were found to be within the composition range of processed cheese. Meanwhile replacing butter fat with vegetable fat at level of 50 and 100% did not considerably affect the chemical composition of cheese analogues. Concentration of total and individual volatile fatty acids of control processed cheese spread were higher than that of processed cheese spread analogue in which milk fat was substituted with vegetable fat at 50 or 100% level. The highest concentration of major short chain volatile fatty acids namely butyric, caproic, caprylic and capric acids were found in control processed cheese spread. Partial substitution of butter fat with peanut cream fat has led to promoted significant modification in the texture, microstructure and sensory properties of processed cheese spread analogue. Control processed cheese spread was firmer than the experimental processed cheese analogue which is related to the presence of high percentage of peanut cream fat. In addition, this treatment decreased the cohesiveness and hardness of the resultant analogue. The size of fat globules increased and the uniformity of their distribution in protein matrix decreased with increased the percentage of vegetable fat used. Control processed cheese spread showed a uniform protein network in which numerous small fat particles were dispersed whilst in processed cheese analogue the fat globules were present in smaller numbers and with greater diameter, a behavior intensified by increasing the proportion of vegetable fat. Control processed cheese spread and processed cheese spread analogue in which butter fat was replaced with peanut cream fat at 50% level had the better sensory characteristics compared with that of analogue made with 100% vegetable fat.

## 1.Introduction

Developed products, known as ‘imitation’ processed cheese spread analogue, are widely produced, and are made from mixtures of dairy and/or non-dairy proteins and dairy fat or vegetable oil (Jihan *et al*., 2017) These products are variously labelled as ‘analogues’, ‘analogs’ imitation’, ‘substitute’, ‘artificial’, ‘extruded’, ‘synthetic’, and/or ‘filled’ (Shaw, 1984; McCarthy, 1990 and Federation, 1995). Imitation cheese spread analogue or cheese spread analogue products are cheese spread analogue like products manufactured by blending water, fat, proteins and other ingredients into a homogeneous mass in the presence of the necessary heat, mechanical shear and emulsifying salts (Guinee, 2003 and Salek *et al*., 2015). The main advantages of this type of cheese spread analogue include its simplicity in production, low manufacturing costs and its amenability to be easily formulated with customized physicochemical and nutritional attributes. Cheese spread analogues have gained importance in different areas. Firstly, largely because of a tremendous increase in the consumption of pizza pie and the fact that cheese spread analogue is among the costliest components of a pizza pie, attention has focused on the development of cheese spread analogue substitutes. In addition, the manufacture of an imitation cheese spread analogue allows manufacturers greater scope in manipulating constituents toward nutritional, textural, and economic ends (Solowiej *et al*., 2014 and Mohamed and Shalaby, 2016). A wide variety of formulated imitation cheese spread analogues in which non-fat milk solids and milk fat are replaced by caseinates and vegetable oils are available in the US (Kiely, McConnell *et al*., 1991). Secondly, due to rapidly increasing prices cheese spread analogue is being gradually priced out of lower income groups. Making cheese spread analogue -like products by substituting the higher priced milk-derived ingredients with lower priced ingredients from vegetable sources may be a possible solution for this economic problem (Guirguis, Abdel Baky *et al*., 1985 and Awad, Salama *et al*., 2014). The cost of producing cheese spread analogues can be considerably less than that of their natural counterparts. As well as savings in the manufacturing process, raw materials are considerably cheaper than milk (Shaw 1984). Thirdly, the short supply of milk production in some parts of the world has led to increased interest in the utilization of substitute ingredients from vegetable sources in producing some dairy analogues (Ahmed and Hassan 1995; McNutt 1989; Bachmann, 2001 and Tamime, 2011). In developing countries where dairy products are expensive and insufficient in quantity, dairy substitutes prepared from legumes provide a nutritious alternative (Santos, Resurreccion *et al*., 1989). Fourthly, there is an ever-increasing interest among consumers in food products which contain less total fat, saturated fat, cholesterol, and calories. Such products are useful in controlling body weight and reducing the risk of heart and artery disease (Kong-Chan, Hellyer *et al*., 1991 and Mortensen, 1991). Thus, cheese spread analogue may offer an excellent opportunity for substituting a traditional product with a new one which offers the same or better nutritional and texture characteristics, by using caseinate as protein sources and the use of polyunsaturated vegetable fats and oils, which produce a cholesterol free product (Giese, 1992 and Kneifel and Seiler, 1993).

It is better to formulate foods with ingredients that help to lower health risks, as in the case of substituting animal fats by vegetable fats and oils, to give foodstuffs low in cholesterol and saturated fat contents (Lobato-Calleros, Vernon-Carter *et al*., 1997). An important area of research for cheese spread analogue is to build up the polyunsaturated fat level, thus improving the health benefits of cheese spread analogue (McNutt, 1989; Bachmann, 2001 and Tamime, 2011). The present work has been carried out to evaluate the effect of replacing butter fat with 50 and 100% of peanut cream on chemical composition, fatty acids, texture properties and sensory evaluation of processed cheese spread analogue.

## 2. Materials and methods

### 2.1.Materials

#### *2.1.1. Cow's milk*

Cow's milk was obtained from dairy technology unit, Faculty of Agriculture, Zagazig University.

#### *2.1.2. Emulsifying Salts and Nisin*

Commercial emulsifying salts (sodium salts of phosphates and polyphosphates) and nisin were obtained from Greenland factory, $10^{th}$ of Ramadan City, Egypt.

***2.1.3. Peanut seeds***

Red-skinned peanut (*Arachis hypogaea*) seeds were purchased from a local market in Zagazig Egypt. Good quality and mold-free seeds were selected.

***2.1.4. Skim milk powder***

The skim milk powder was purchased from private dairy plant in Zagazig Egypt. Chemical characteristics **(**Butterfat 1.25% max – moisture 4.00% max– protein (n x 6.38) 35.5% approx. – lactose 51.0% approx. – minerals/ashes 8.50% approx. – titratable acidity 0.15% max – solubility index 1.25 ml max– sediment / scorched particles disc b max– wpn index not more than 1.5 mg/g).

***2.1.5. Sucrose***

Good quality sucrose was obtained from a local market in Zagazig, Egypt.

***2.1.6. Ras cheese***

Ras cheese which was made by the method of (Abdel-Hamid, El-Shabrawy *et al*., 2000) at the Department of Food Science, Faculty of Agriculture, Zagazig University, Zagazig, Egypt was used in the preparation of cheese spread analogue.

***2.1.7. Butter***

Butter was obtained from Dairy Technology Unit, Faculty of Agriculture, Zagazig University, Zagazig, Egypt and used in the preparation of cheese spread analogues.

***2.1.8. Starch***

Maize starch was obtained from the local market in Zagazig, Egypt.

***2.1.9 Chemicals***

All chemical used in this analysis was of analytical grade quality.

**2.2.Methods**

***2.2.1. Preparation of peanut milk and peanut cream***

Peanut-milk was prepared by the method described by (Isanga and Zhang, 2009). Briefly, sorted peanut seeds were roasted (130°C for 20 min), de-skinned and soaked in 0.5 g/100 ml $NaHCO_3$ at 5°C for 12 h. After washing with water, the kernels were then mixed with water at a ratio of 1:5 W/V (peanuts (g): water (ml), transferred to a blender, and blended for at least 5 min. Resultant formed slurry was filtered using three-layered cheese cloth to obtain peanut milk. Then it was pasteurized at 71°C/15 seconds. cooled and stored at freezer (- 10°C) till uses. Peanut cream was prepared at Dairy Technology Unit, Faculty of Agriculture, Zagazig University. Peanut milk was prepared as described before then cream was separated using milk separator. The separator was flush with warm water to be clean and warm. Peanut milk was heated to 45°C, then poured into the bowl and permit to pass it through the central tubular shaft with turning on the motor and crank for 10 minutes, the force of spin causes the peanut cream to separate from the peanut milk. The resultant peanut cream was stored in the refrigerator at 5°C after pasteurization until usage.

***2.2.2. Manufacture of processed cheese spread analogue***

Control processed cheese spread and other cheese analogue containing 50 and 100% peanut cream were manufactured with the following formulation as shown in Table 1.

**Table 1**.Formulation of different ingredients set in processed cheese analogue spread preparation (Total batch 1500 g).

| Ingredients | Substitution levels of milk fat by peanut cream | | |
|---|---|---|---|
| | **0%** | **50%** | **100%** |
| **Mature Ras cheese** | 127.50 | 120 | 112.50 |
| **Fresh Ras cheese** | 510 | 480 | 468.75 |
| **Butter** (84% fat) | 107.25 | 59.25 | - |
| **Peanut cream** (45% fat) | - | 108.30 | 224.70 |
| **Starch** | 30 | 30 | 30 |
| **Skim milk powder** | 60 | 58.50 | 52.50 |
| **Emulsifying Salts** | 37.50 | 37.50 | 37.50 |
| **Water** | 627.75 | 606.45 | 574.05 |
| **Total** | **1500** | **1500** | **1500** |

Manufacture of processed cheese spread of all treatments as done in the Dairy Technology Unit, Food Science Department, Faculty of Agriculture, Ain Shams University. Mature (2 months) and fresh Ras cheese were cut into small portions suitable to be fed through the inlet of a shredding machine (Braun mixer, Germany). The suitable amounts of ingredients including; fresh Ras cheese, mature Ras cheese, butter, water, maize starch, skimmed milk powder emulsifying salt and nisin were added consecutively in a laboratory style-processing kettle locally made in Egypt. Specifications of the cooking machine are mentioned by (Awad, 1996).

The ingredients were mixed for about 1 min before processing. The blends were adjusted to contain 58% moisture, 50% fat/dry matter, 3% emulsifying salt, 0.01% nisin in the finished product. The mixture was cooked for 10 min at 85-90°C using indirect steam at pressure 2-2.5 kg/cm$^2$. The melted processed cheese spread analogue of the different treatments was poured into wide mouth glass jars (150g) sealed with sterilized aluminum foil and capped directly after filling. The resultant processed cheese spread analogue was cooled at room temperature stored at 5°C for 3 months. Samples were taken and subjected to the different analyses when fresh and after 1, 2 and 3 months of storage.

Using a similar manufacturing process, a series of imitation cheese spread analogues were prepared by replacing 50% of butter fat with peanut cream fat and 100% of butter fat with peanut cream containing 45% fat.

### *2.2.3. Chemical analysis*

#### *2.2.3.1. Gross chemical composition*

Moisture, fat, protein, pH and acidity contents of processed cheese spread and its analogue were determined according to (AOAC, 2006).

#### *2.2.3.2. Fatty acids Analysis*

Fatty acids were determination (as % of total). Fatty acids were extracted and determined as methyl esters (AOAC, 2006). The methylesters were prepared by weighing a 10 mg sample in a 2 ml test tube (with screw cap). The sample was dissolved in 1 ml hexane followed by the addition of 10 ml of 2 N potassium hydroxide. The tube was closed and vortex for 30 seconds. Analysis was carried out by Gas chromatography Ultra trace GC DSQ (Thermo scientific USA). TR-FAMe capillary column (Thermo scientific USA) (30 m length × 0.22 mm ID × 0.25 micron film thickness). For analysis fatty acid methyl esters, Cis/trans isomers, 70% cyano-propyl polysilphenylene – siloxane was used. Helium was employed as carrier gas, with constant flow 0.8ml/min. the temperature of injector was set at 200°C, then 1 µl was injected. The operating condition were as follow: oven temperature was held at 40°C for 1 min and then increased by 10°C/min to 180°C and held for 2 min increased again to 210°C at 4°C/min held for 3 min at 210°C, increased again to 250 at 10°C/min and finally isotherm at 250°C for 10 min. Scan mode was full scanning mass 50-650. Mass detector was used. Results were expressed as percent of relative area (Dabbou, Issaoui *et al*., 2009).

#### *2.2.3.3. Texture profile analysis*

Texture profile analysis of processed cheese spread analogue was determined according to (Bourne, 2002) by a universal testing machine

(Cometech, B type, Taiwan) provided with software. An Aluminum 25mm diameter cylindrical probe was used in a "texture profile analysis" (TPA) double compression test to penetrate to 50% depth, at 1 mm/ s speed test. firmness (N), gumminess (N), chewiness (N), adhesiveness (N.s), cohesiveness, springiness and resilience were calculated from the TPA graphic. Texture determinations were carried out in (40 x 40 x 30) mm-sized samples.

*2.2.3.4. Micro-structural analysis*

Micro-structural analysis of processed cheese spread analogue was determined using scanning electron microscopy (SEM).

Tissue pieces were fixed in 4% glutaradehyde in 0.2M sodium acodylate buffer (pH 7.3) for 4 hour, followed by post fixation in osmium tetra oxide SO4 for 2 hour. Then rinsed three times in the same buffer (sodium cacodylate buffer). The samples were dehydrated through a graded ethanol series from 10 to 100%, 10 minutes in each one except the finely one 100% for 30 minutes for three changes (each one for 10min.), then dehydrated using critical point dried instrument with liquid carbon dioxide ($CO_2$). The speciments were mounted on cupper stubs with double- sided adhesive tape, coated with gold using S150A Sputter Coated – Edwards – England. The specimens viewed in a scanning electron microscope JXA-840A Electron Probe Microanalyzer – JEOL – Japan.

*2.2.3.5.Sensory evaluation of processed cheese spread analogue*

Sensory analysis was performed according to the methodology described by (Meilgaard, Carr *et al*., 2006). The acceptance test was carried out using a 9-point structured hedonic scale, for the attributes of appearance, colour, flavour, creaminess, firmness, spreadability and overall impression. Based on 9 point hedonic scale; like extremely=9, like very much =8, like moderately =7, like slightly =6, neither like nor dislike =5, dislike slightly =4, dislike moderately =3, dislike very much =2, dislike extremely =1. About 20 g of each sample were served, at approximately 7°C, in white 50 ml plastic cups coded with random three digit numbers. A plastic knife and three cream cracker type biscuits were offered together with the sample, for the evaluation of spreadability. The differences between the scores were evaluated at the 5% level of significance, comparing the means using the Duncan's test.

### *2.2.4.Statistical analysis*

Results were statistically analyzed using a computer program "SAS system for windows version 9.00 TS M0" (SAS 2008) for analysis of variance by one way (ANOVA) and comparison of means by Duncan's multiple comparison test where $P < 0.05$ was considered for significant difference.

## 3.Results and discussions

### 3.1. Changes of Chemical Composition of processed cheese analogue during storage.

The changes in chemical composition of cheese spread analogue samples prepared with different levels of peanut cream during storage for 3 months are shown in Table (2).

**Table 2**. Effects of replacing butterfat with peanut cream fat on the chemical composition of processed cheese spread analogue during storage at 5°C.

| Characteristics (%) | Storage time (months) | Cheese spread analogue containing peanut cream | | |
|---|---|---|---|---|
| | | 0% (control) | 50 % | 100% |
| Moisture | 1 | 59.57±0.11$^{f}$ | 60.20±0.11$^{d}$ | 57.15±0.10$^{h}$ |
| | 2 | 62.32±0.10$^{a}$ | 60.29±0.16$^{c}$ | 59.78±0.11$^{e}$ |
| | 3 | 60.94±0.16$^{b}$ | 60.25±0.12$^{c}$ | 58.46±0.10$^{g}$ |
| Ash | 1 | 4.78±0.03$^{a}$ | 4.50±0.03$^{cde}$ | 4.50 ±0.03$^{cde}$ |
| | 2 | 4.56±0.03$^{c}$ | 4.43±0.03$^{e}$ | 4.55 ± 0.03$^{c}$ |
| | 3 | 4.67±0.03$^{b}$ | 4.46±0.03$^{de}$ | 4.52±0.03$^{cd}$ |
| Protein | 1 | 12.46±0.27$^{b}$ | 12.13±0.26$^{e}$ | 13.19±0.29$^{a}$ |
| | 2 | 12.35±0.27$^{d}$ | 12.09±0.26$^{g}$ | 11.49±0.25$^{h}$ |
| | 3 | 12.40±0.27$^{c}$ | 12.11±0.26$^{f}$ | 12.34±0.27$^{d}$ |
| Fat/dry matter | 1 | 50.82±0.14$^{g}$ | 52.11±0.14$^{d}$ | 50.78±0.12$^{g}$ |
| | 2 | 54.51±0.13$^{a}$ | 50.31±0.17$^{h}$ | 53.08±0.15$^{b}$ |
| | 3 | 52.24±0.10$^{c}$ | 51.22±0.16$^{f}$ | 51.68±0.17$^{e}$ |
| pH | 1 | 5.79±0.16$^{bc}$ | 5.86±0.10$^{a}$ | 5.88±0.14$^{a}$ |
| | 2 | 5.75±0.14$^{c}$ | 5.85±0.14$^{a}$ | 5.76±0.10$^{bc}$ |
| | 3 | 5.77±0.13b$^{c}$ | 5.85±0.13$^{a}$ | 5.80±0.11$^{b}$ |

Means having the same letters in the same row are not significantly different.

The obtained results showed that both the control cheese and cheese spread analogue containing peanut cream were found to be within the compositional range of processed cheese (Muir, Tamime *et al*., 1999). It is interesting to note that both levels of vegetable fat i.e., 50 and 100% exhibited little observable effects on the chemical composition of cheese analogues. There were significant differences between the control and only cheese analogue containing 100% peanut cream fat in all the chemical components (moisture, fat, protein and ash contents and pH value). These differences between cheese analogues and control cheese reflected the differences between formulations. The general trend of the chemical composition of control processed cheese and processed cheese analogues are in agreement with those reported by (Tamime, Muir *et al*., 1999). They found that the total solids and protein contents were higher in cheese analogues than the control, while the fat and ash contents and pH values were lower in cheese prepared with peanut cream than the control. The same trend was also mentioned by (Cunha, Dias *et al*., 2010), who reported that the analogue cheeses were higher in protein and lower in salt content and pH values than control.

The differences in protein levels, fat content, ash content, moisture and pH values were significant within all models of processed cheese analogue tested (including control samples). The differences in chemical profile between samples reflected differences between formulations.

### 3.2. Fatty acid composition of processed cheese spread analogue

Twenty fatty acids were detected in different processed cheese spread analogue, wherein palmitic and oleic acids were the main fatty acids. Both fatty acids accounted together more than 60% of total fatty acids. Myristic and stearic acids were detected also in high levels in different processed cheese spread analogues.

#### *3.2.1.Volatile fatty acids*

Fig. 1 shows the amounts of individual volatile fatty acids ($C_4$-$C_{10}$) in both control and processed cheese analogue spread containing 50 and 100% of peanut cream after 2 months of storage.

Considerable levels of short chain fatty acids were also detected in different cheese spread analogue Fig. (1) shows the effect of replacing butter fat with peanut cream fat on the volatile fatty acids in processed cheese spread analogue.

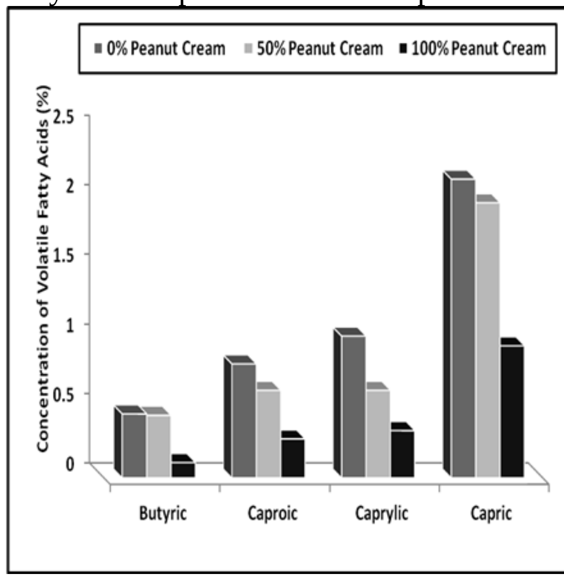


**Figure 1.** The effect of replacing butterfat with peanut cream fat on the volatile fatty acids in processed cheese spread analogue.

Free fatty acids (FFA) are major contributors to the flavour of cheese (Kilcawley, Wilkinson *et al*., 2006). The latter are released upon lipolysis and the short and intermediate-chain FFAs contribute directly to cheese flavour. These short and intermediate-chain fatty acids ($C_4$–$C_{12}$) have relatively low perception thresholds and each gives a characteristic flavour note. Butanoic acid ($C_4$) contributes “rancid” and “cheesy” flavours while hexanoic acid ($C_6$) has a “pungent”, “blue cheese” flavour note (Collins, McSweeney *et al*., 2003). Depending on their concentration and perception threshold, volatile fatty acids can either contribute positively to the aroma of the imitation cheese or to a rancid defect. (Noronha, Cronin *et al*., 2008) obtained similar results of volatile fatty acids in enzyme modified cheese.

The detected 4 volatile fatty acids were butyric, caproic, caprylic and capric acids. The higher concentration of volatile fatty acids could be explained on the basis that peanut cream did not contain any volatile fatty acids. The obtained results showed that the amounts of total and individual volatile fatty acids of control processed cheese spread were higher than processed cheese analogue spreads containing 50% or 100% peanut cream. The highest concentration of major short chain FFA (volatile fatty acids) was butyric acid, Capric acid, caprylic acid, caproic and in the control. Cheese containing peanut cream showed lower concentration of these fatty acids as compared to the control. This could be explained on the basis that milk contains short chain fatty acids ($C_4$-$C_{10}$) whereas peanut cream fat did not contain any volatile fatty acids.

Fig. (2) shows the non-volatile saturated fatty acids profile of different processed cheese spread analogue. It could be noted that different processed cheese spread analogues resulted in significant change in fatty acids profile of various processed cheese spread analogues. However, the changes were notably in the levels of the main fatty acids (palmitic, oleic acids, myristic and stearic), the same trend was also mentioned by (Cunha, Grimaldi *et al*., 2013).

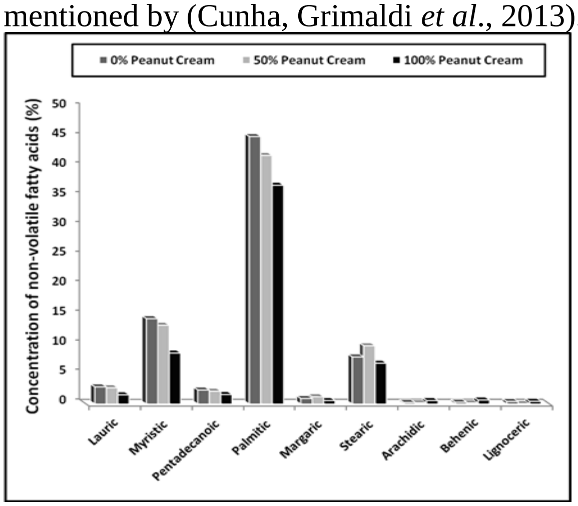


**Figure 2**. The effect of replacing butter fat with peanut cream fat on the non-volatile fatty acids in processed cheese spread analogue.

### *3.2.2.Mono Unsaturated fatty acids*

Fig. (3) Shows the effect of replacing butter fat with peanut cream fat on the mono unsaturated fatty acids after two months of storage at room temperature.

The replacing of butter fat with peanut cream fat significantly affected the concentration of oleic acid as the major monounsaturated fatty acids in processed cheese spread analogue the same trend was also mentioned by (Cunha, Grimaldi *et al*., 2013).

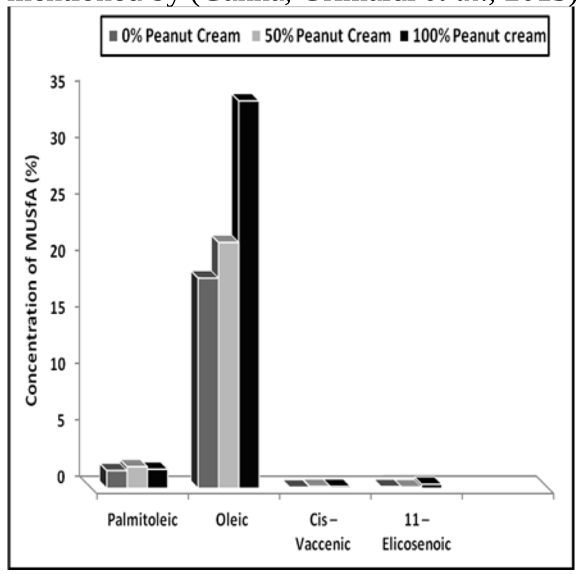


**Figure 3.** The effect of replacing butter fat with peanut cream fat on the monounsaturated fatty acids in processed cheese spread analogue.

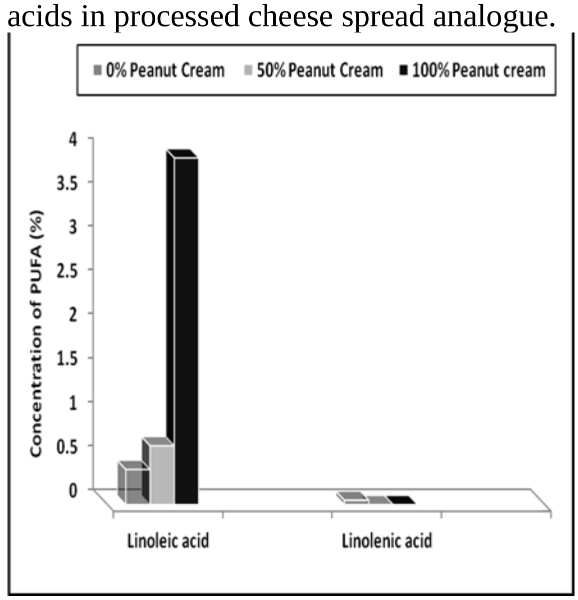


**Figure 4.** The effect of replacing butter fat with peanut cream fat on the polyunsaturated fatty acids in processed cheese spread analogue.

The level of these fatty acids in processed cheese analogue containing both 50 and 100% peanut cream was higher than the control.

The palmitoleic acid was also found in lower concentration in both control cheese and cheese containing peanut cream.

### *3.2.3.Polyunsaturated fatty acids*

Fig. (4) Shows the effect of replacing of butter fat with peanut cream fat on the poly unsaturated fatty acids of processed cheese analogue after two months of storage at room temperature. Substitution of butter fat with peanut cream fat significantly affected the concentration of linoleic acid as the dominant fatty acids in polyunsaturated fatty acids of processed cheese spread analogue. The level of these fatty acids in processed cheese analogue containing both 50 and 100% peanut cream was higher than the control. This was more pronounced in processed cheese analogue spread containing 100% peanut cream.

### *3.2.4.Total saturated and unsaturated fatty acids*

It is known that the excessive consumption of saturated fatty acids is related to the increase of the plasmatic cholesterol and the obesity (Sales, Costa *et al*., 2005). On the other hand, the consumption of polyunsaturated (PUFA) and monounsaturated fatty acids (MUFA) it has been recommended to improve the lipidic profile in relation to the saturated fatty acids.

Fig. (5) Shows the effect of replacing of butter fat with peanut cream fat on the total saturated and unsaturated fatty acids of cheese analogue after two months of storage at 5° C. The substitution of butter fat with peanut cream fat significantly affected the concentration of linoleic acid as the dominant fatty acids in poly unsaturated fatty acids of cheese spread analogue.

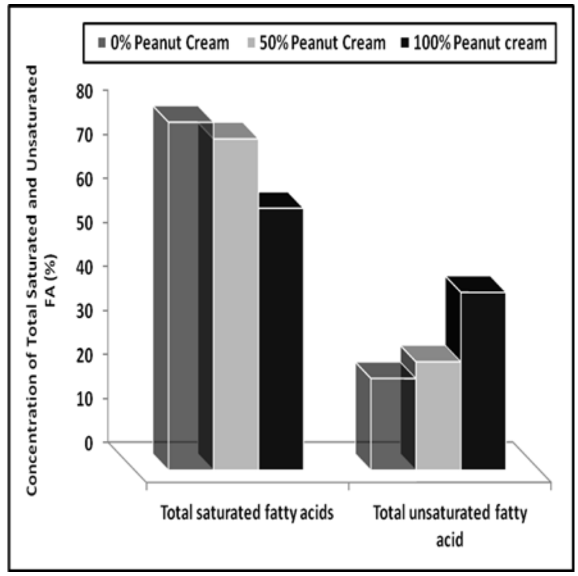


**Figure 5.** The effect of replacing butter fat with peanut cream fat on the total saturated and unsaturated fatty acids in processed cheese spread analogue.

The level of these fatty acids in cheese analogue containing both 50 and 100% peanut cream was higher than the control. This was more pronounced in cheese analogue spread containing 100% peanut cream.

### 3.3. Texture profile

Fig. (6) shows the profile texture of processed cheese spread analogue made by replacing 50 and 100% of butter fat with peanut cream fat in the formulation used in the preparation of imitation cheese spread analogue.

With respect to the firmness, the control cheese spread was firmer than the experimental processed cheese spread analogues, which is related to the presence of a high percentage of replacement of peanut cream fat. In the analogues, since the diameter of fat globules were greater, there was a greater protein mass per unit area of the fat. Such a high protein density has been associated with elevated firmness, since the protein matrix is the structural component conferring greater resistance to deformation (Bryant, Ustunol *et al*., 1995 and Lobato-Calleros, Vernon-Carter *et al.*, 1999).

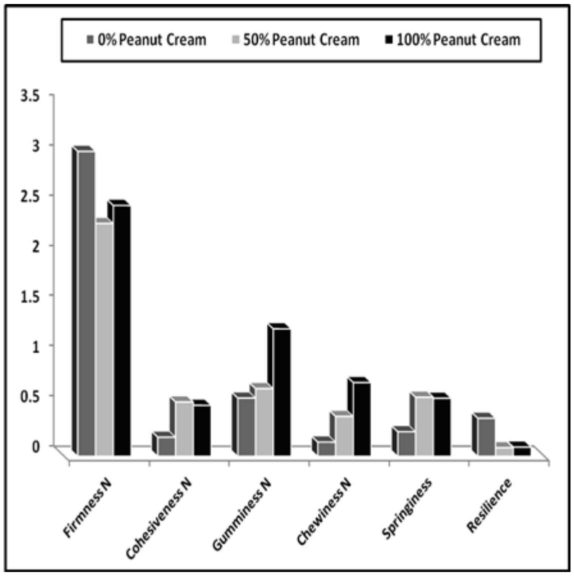


**Figure 6.** Effect of replacing butter fat with peanut cream fat on the texture profile of processed cheese spread analogue.

In this work, analogues of this cheese, made by substituting 50% and 100% of the dairy fat with vegetable fat, were studied with respect to physical–chemical composition, texture profile, microstructure and sensory acceptance. The substitution of part of the dairy cream by vegetable fat resulted in increased adhesiveness and hardness. The traditional cheese presented a uniform protein network, in which numerous small fat particles were dispersed, whilst in the analogues, the fat globules were present in smaller numbers and with greater diameters, a behavior intensified by increasing proportions of vegetable fat. In the sensory analysis, the traditional cheese and the analogue with 50% vegetable fat were better evaluated than the analogue with 100% vegetable fat.

The processed cheese analogues also showed greater values for cohesiveness than the traditional processed cheese spread analogue. Since there was no difference in the chemical compositions, the type of fat was probably responsible for this behavior. The differences in microstructure found were also probably associated with the increase in cohesiveness, since the protein network structure and extent of the interactions between the fat and the casein influence the degree of coherence between the product and the surface with which it is in contact. The results found are in agreement with the observations of (Lobato-Calleros, Vernon-Carter *et al.*, 1997 and Cunha, Dias *et al*., 2010). They found that the addition of soybean fat increased the adhesiveness and hardness of the processed cheese spread analogues.

Control had the lowest gumminess and chewiness values followed by the R1 and the R2 groups (Fig. 6). But, no significant differences were found with respect to springiness, cohesive-ness ($P>0.05$). (Lobato-Calleros, Vernon-Carter *et al.*, 1999) stated that soybean fat conferred hardness and adhesiveness to the processed cheese analogue however decreased cohesiveness and springiness. Hydrogenated cottonseed oil in-creased hardness but decreased cohesiveness in both imitation groups.

## Microstructure Evaluation

The rheological properties of processed cheese spread analogue are of considerable importance as they affect: its handling, portioning and packing characteristics; its texture and eating quality, as they determine the effort required to masticate the processed cheese spread analogue or alternatively the level of mastication.

The partial or total substitution of butter fat by peanut cream fat into processed cheese spread analogue caused significant modification on the instrumental textural characteristics of hardness, adhesiveness, cohesiveness and chewiness, but no significant ($p>0.05$) variations in springiness were detected (Fig. 7).

Figures (7–9) show the photomicrographs of the microstructure of the control cheese spread and its analogues with 50% and 100% of peanut cream (vegetable fat), respectively, with the same magnitude (330x). In typical scanning electron micrographs of cheese spread analogue, a protein matrix is visible with various forms and sizes of open spaces, representing the fat globules that were extracted during sample preparation for analysis (Tamime and Robinson, 1999).

Fig. 7 illustrate the Scanning Electron Micrograph (SEM) of control processed cheese spread. This figure clearly shows that this type of structure could be observed in all the samples studied. The control processed cheese spread analogue presented numerous small particles of fat dispersed in a uniform protein network.

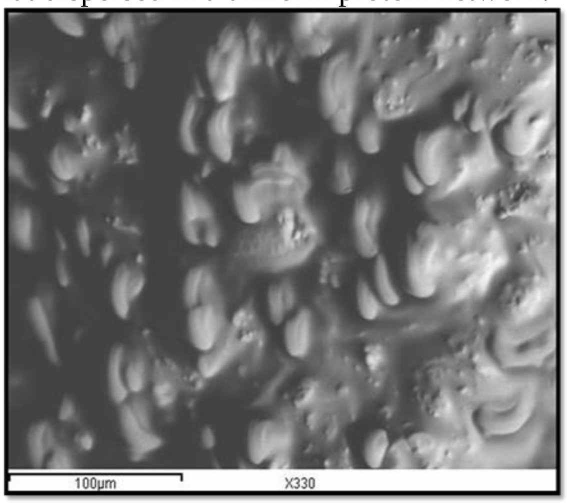


**Figure 7.** Scanning electron micrograph (SEM) of control processed cheese spread (Magnitude 330x at 100 µm).

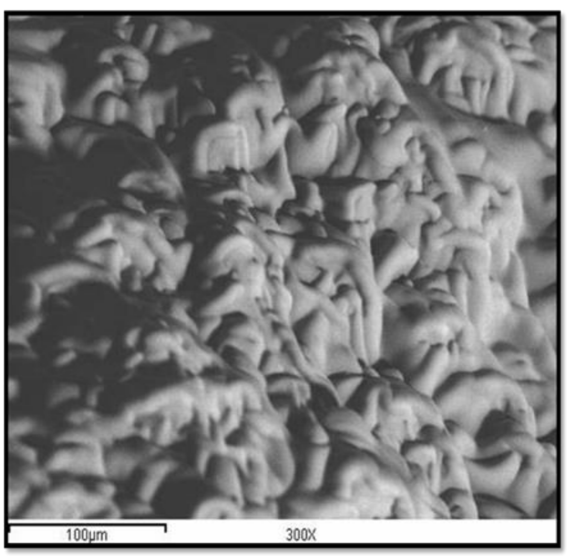


**Figure 8.** Scanning electron micrograph (SEM) of processed cheese spread analogue made by replacing 50% of butter fat with peanut cream fat (Magnitude 330x at 100 µm).

The fat globules are predominantly spherical and distributed uniformly throughout the protein matrix. The obtained results are in agreement with those obtained for processed cheese spread analogue by (Mistry and Anderson 1993 and Tamime, Kalab *et al*., 1990).

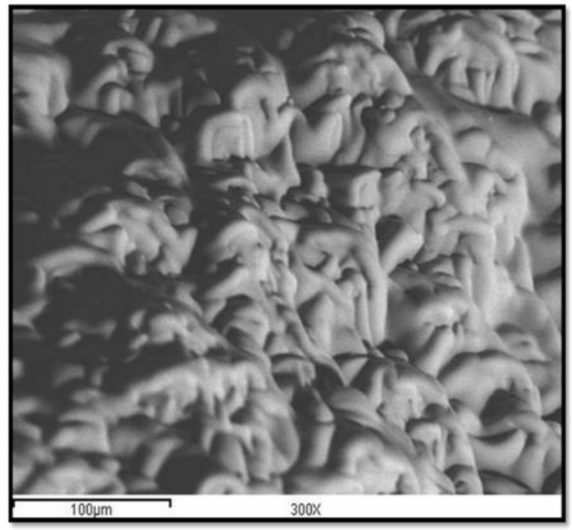


**Figure 9.** Scanning electron micrograph (SEM) of processed cheese spread analogue made by replacing 100% of butter fat with peanut cream fat (Magnitude 330x at 100 µm).

On the other hand, in the analogues the fat globules were greater in diameter. In addition, they were less uniformly distributed throughout the protein matrix than in the control processed cheese spread analogue.

Comparing the microstructures of the analogues with 50% (Fig. 8) and 100% (Fig. 9) of peanut cream, it can be seen that an increase in the percentage of vegetable fat resulted in a decrease in the number of fat globules and an increase in their diameters.

The vegetable fat used was composed mainly of fatty acids with more than 16 carbons (Table 2), conferring a highly hydrophobic characteristic and increasing the number of primary bonds, resulting in larger and more irregular crystals and globules. On the other hand, the milk fat presenting a greater proportion of saturated fatty acids contained a significant amount of low molecular weight, fatty acids, which reduced its non-polar nature, decreasing the attractive forces between the fat globules and increasing the affinity with the protein network.

In the control processed cheese spread, the fat droplets were small and uniformly distributed, while in the analogues fat globules presented a wider range of particle size. Increasing the percentage of peanut cream from 50% to 100% resulted in even larger fat droplets, which corroborates the results observed in the micrographs.

The textural characteristics of the processed cheese spread analogue are determined by the combined structural properties of the protein matrix and the fat droplets immersed in the former. As fat content is reduced, more non-interrupted protein zones compose the cheese spread analogue structure. In consequence, a high degree of crosslinking of protein molecules occurs resulting in three dimensional networks, exhibiting high resistance to the deformation (Bryant, Ustunol *et al*. 1995 and Lobato-Calleros, Robles-Martinez *et al*., 2001).

The main factor determining the textural characteristics in processed cheese spread analogue is the protein matrix structure, and it has been reported that high protein densities in processed cheese spread analogue are associated with high values of hardness (Bryant, Ustunol *et al*., 1995).

Milk fat contributed to the increase of all the textural characteristics, although its effect on cohesiveness was marginal, whereas on chewiness it was more pronounced (Figure 4). It has been demonstrated that butter milk globule sizes are larger and more heterogeneous than those for emulsified vegetable oils, so the number of the former per unit volume are lower than those of the latter.

On the other hand, milk fat has the highest melting point fatty acids than control conferring increased resistance to structure deformation, and thus an increased chewiness ( Lobato-Calleros, Vernon-Carter *et al.*, 1999). Due to the slightly more lipophilic nature of EB, it had a relatively low effect on displacing protein from the oil in water interface (Euston, Singh *et al*., 1996) so that interactions between fat globules and the protein matrix were favored resulting in increased cohesiveness (Fig. 6).

Substitution of part of the butter (84% fat) with peanut cream (45% fat) as a vegetable fat promoted significant modifications in the texture and principally in the microstructure of the processed cheese spread analogue The size of the fat globules increased and the uniformity of their distribution in the protein matrix decreased with an increase in the percentage of vegetable fat used.

The porous network in the microstructure of the control process cheese spread analogue (Fig. 6) was similar to that of the internal structure of Edam and Gouda cheese spread analogue as reported by (Schmidt, 1982). Since both higher fat and water contents can lower the firmness of cheese spread analogue (Kalab, 1993).

### 3.4. Sensory evaluation

Table 3 shows the mean scores attributed to each of the parameters evaluated: appearance, color, flavour, creaminess firmness, spread ability and overall impression.

**Table 3**. Organoleptic scores for control processed cheese spread and processed cheese spread analogues containing 50 and 100% peanut cream fat.

| **Attributes** | **Cheese spread analogue containing peanut cream** | | |
|---|---|---|---|
| | **0 %** | **50 %** | **100 %** |
| **Appearance** | 7.1[a] | 6.7[a] | 5.5[b] |
| **Colour** | 6.9[a] | 6.4[a] | 5.7[b] |
| **Flavour** | 7.8[a] | 6.3[b] | 5.6[c] |
| **Creaminess** | 6.9[a] | 6.9[a] | 5.8[b] |
| **Firmness** | 6.8[a] | 6.7[a] | 5.6[b] |
| **Spreadability** | 7.4[a] | 6.4[b] | 5.9[c] |
| **Overall Impression** | 7.3[a] | 6.7[b] | 5.5[c] |

* Means having the same letters in the same row are not significantly different.

All the products received means above 5.5 for all the attributes evaluated, showing that they were well accepted by the panelists. The analogue containing 50% of peanut cream presented acceptably by the panelists, and for the attributes of appearance, color, creaminess and firmness, this analogy was more preferred than all the other products tested, including the control processed cheese spread analogue. Flavour was the only parameter for which the control processed cheese spread analogue received significantly higher ($p < 0.05$) mean scores than processed cheese spread analogue containing 50 and 100% of peanut cream fat, showing the importance of dairy fat on the flavor of dairy products.

Although neither of the analogues managed to imitate the flavour of the traditional processed cheese spread analogue, all showed gained acceptable quality. With respect to some of the attributes such as colour, firmness and creaminess, the analogue with 50% vegetable fat was better evaluated than 100% fat cheese spread analogue. This shows that there are good possibilities for successfully substituting traditional processed cheese spread (control) with an analogue manufactured with 50% peanut cream fat. (Abdel-Baky, *et al*., 1987) stated that the processed spread cheese made from Ras cheese revealed better flavour and appearance during storage at both refrigerator and at room temperatures. (Kebary, *et al.*, 1998) reported that the scores of organoleptic properties of spread cheese made from different blends decreased as storage period progressed except the scores of colour. (Razig and Yousif, 2010) showed that the best score of appearance, texture, flavour and overall acceptability was obtained in spread processed cheese containing 5% skim milk powder compared with others processed cheeses samples. They also found that 3 months were found to be quite satisfactory to attain good quality spread cheese.

## 4. Conclusions

Both levels of vegetable fat 50 and 100% exhibited significant small effects on the chemical composition of cheese analogues. The highest concentration of major short chain volatile fatty acids (VFA) was butyric acid, capric acid, caprylic acid and caproic acid in the control-processed cheese. Firmness of the control processed cheese spread was firmer than the experimental processed cheese spread analogues. Substitution of part of the butter fat with peanut cream led to promoted significant modifications in the texture, the sensory properties, the colour and, principally, in the microstructure of the processed cheese spread analogue. Regarded to the sensory analysis, the control processed cheese spread and the analogue with 50% vegetable fat had better characteristics than the analogue with 100% vegetable fat.

## 5.References

Abdel-Baky, A., El-Neshawy, A., Farahat, S., El Desoki, E. (1987). The use of Ras cheese made by direct acidification in the manufacture of processed cheese spread. *Egyptian Journal of Dairy Science*, 15, 273-285.

Abdel-Hamid, L.B., El-Shabrawy, S., Awad, R., Singh, R. (2000). Chemical properties of processed Ras cheese spreads as affected by emulsifying salt mixtures. *Journal of food processing and preservation*, 24(3), 191-208.

Ahmed, N., Hassan, F. (1995). Utilization of plant proteins in manufacture of cheese analogs. *Egyptian Journal of Food Science*, (Egypt).

AOAC (2006). Official Methods of Analysis. 18th Edn., Association of Official Analytical Chemists Inc., Arlington, TX., USA.

Awad, R. (1996). Studies on emulsifying salt mixtures for processed cheese.

Awad, R.A., Salama, W.M., Farahat, A.M. (2014). Effect of lupine as cheese base substitution on technological and nutritional properties of processed cheese analogue. *Acta Scientiarum Polonorum Technologia Alimentaria*, 13(1), 55-64.

Bachmann, H.P. (2001). Cheese analogues: a review. *International dairy journal*, 11(4-7), 505-515.

Bourne, M. (2002). Food texture and viscosity: concept and measurement. Elsevier.

Bryant, A., Ustunol, Z., Steffe, J. (1995). Texture of Cheddar cheese as influenced by fat reduction. *Journal of food science*, 60(6), 1216-1219.

Collins, Y.F., McSweeney, P.L., Wilkinson, M.G. (2003). Lipolysis and free fatty acid catabolism in cheese: a review of current knowledge. *International dairy journal*, 13(11), 841-866.

Cunha, C.R., Dias, A.I., Viotto, W.H. (2010). Microstructure, texture, colour and sensory evaluation of a spreadable processed cheese analogue made with vegetable fat. *Food Research International*, 43(3), 723-729.

Cunha, C.R., Grimaldi, R., Alcantara, M.R., Viotto, W.H. (2013). Effect of the type of fat on rheology, functional properties and sensory acceptance of spreadable cheese analogue. *International Journal of Dairy Technology*, 66(1), 54-62.

Dabbou, S., Issaoui, M., Servili, M., Taticchi, A., Sifi, S., Montedoro, G.F., Hammami, M. (2009). Characterisation of virgin olive oils from European olive cultivars introduced in Tunisia. *European journal of lipid science and technology*, 111(4), 392-401.

Euston, S.E., Singh, H., Munro, P.A., Dalgleish, D.G. (1996). Oil-in-water emulsions stabilized by sodium caseinate or whey protein isolate as influenced by glycerol monostearate. *Journal of food science*, 61(5), 916-920.

Federation, I.D. (1995). Consumption statistics for milk and milk products. Bull International Dairy Federation 301, 14-16.

Giese, J. (1992). Developing low-fat meat products. *Food technology*, (USA).

Guinee, T. (2003). Role of protein in cheese and cheese products, *Advanced Dairy Chemistry: Proteins*. Springer, pp. 1083-1174.

Guirguis, A., Abdel Baky, A., El-Neshawy, A., El-Shafey, N. (1985). Peanut curd in the manufacture of processed cheese-like product [Egypt]. *Zagazig Journal of Agricultural Research*, (Egypt).

Isanga, J., Zhang, G. (2009). Production and evaluation of some physicochemical parameters of peanut milk yoghurt. *LWT-Food Science and Technology*, 42(6), 1132-1138.

Jihan Mohamed Kassem, Hayam Mohamed Abbas, Ashraf Gaber Mohamed, Wafaa Kamel Bahgaat and Tamer Mohammed El-Messery (2017). Sweet processed cheese spread analogue as a novel healthy dairy product. *International Journal Dairy Science*, 12: 331-338.

Kalab, M. (1993). Practical aspects of electron microscopy in dairy research. *Food Structure*, 12(1), 11.

Kebary, K., Abeid, A., Badawi, R. (1998). Impact of fat replacers on properties of low fat processed cheese spread, 7. Egyptian Conference for Dairy Science and Technology, Cairo (Egypt), 7-9 Nov 1988.

Kiely, L., McConnell, S., Kindstedt, P. (1991). Observations on the Melting Behavior of Imitation Mozzarella Cheese1. *Journal of dairy science*, 74(10), 3568-3572.

Kilcawley, K.N., Wilkinson, M.G., Fox, P.F. (2006). A novel two-stage process for the production of enzyme-modified cheese. *Food Research International*, 39(5), 619-627.

Kneifel, W., Seiler, A. (1993). Water-holding properties of milk protein products-A review. *Food Structure*, 12(3), 3.

Kong-Chan, J.L., Hellyer, J.A., Tafuri, M.W. (1991). Simulated cheese products with reduced animal fat and calories. Google Patents.

Lobato-Calleros, C., Robles-Martinez, J., Caballero-Perez, J., Vernon-Carter, E., Aguirre-Mandujano, E. (2001). Fat Replacers in Low-Fat Mexican Manchego Cheese. *Journal of Texture Studies* 32(1), 1-14.

Lobato-Calleros, C., Vernon-Carter, E., Guerrero-Legarreta, I., Soriano-Santos, J., Escalona-Beundia, H. (1997). Use of fat blends in cheese analogs: Influence on sensory and instrumental textural characteristics. *Journal of Texture Studies*, 28(6), 619-632.

Lobato-Calleros, C., Vernon-Carter, E., Sanchez-Garcia, J., Garcia-Galindo, H. (1999). Textural characteristics of cheese analogs incorporating fat replacers. *Journal of Texture Studies*, 30(5), 533-548.

McCarthy, J., (1990). Part 3. World Dairy Situation 1990–Butter: the World Market–Imitation Cheese Products, 45-52.

McNutt, K. (1989). Cheese analogs. *Food Engineering*, 61, 76-79.

Meilgaard, M.C., Carr, B.T., Civille, G.V., (2006). *Sensory evaluation techniques*. CRC press.

Mistry, V., Anderson, D. (1993). Composition and microstructure of commercial full-fat and low-fat cheeses. *Food Structure*, 12(2), 13.

Mohamed, A.G., Shalaby, S.M. (2016). Texture, chemical properties and sensory evaluation of a spreadable processed cheese analogue made with apricot pulp (Prunus armeniaca L.).*International Journal Dairy Science*, 11, 61-68.

Mortensen, H. (1991). Imitation cheese products will gain importance. *Scandinavian Dairy Information* (Sweden).

Muir, D., Tamime, A., Shenana, M., Dawood, A. (1999). Processed cheese analogues incorporating fat-substitutes 1. Composition, microbiological quality and flavour changes during storage at 5 C. *LWT-Food Science and Technology*, 32(1), 41-49.

Noronha, N., Cronin, D.A., O'Riordan, E.D., O'Sullivan, M. (2008). Flavouring of imitation cheese with enzyme-modified cheeses (EMCs): Sensory impact and measurement of aroma active short chain fatty acids (SCFAs). *Food chemistry*, 106(3), 905-913.

Razig, K.A.A., Yousif, A.M. (2010). Utilization of groundnut milk in manufacturing spread cheese. *Pakistan Journal of nutrition*, 9(4), 314-319.

Salek, R.N., Cernikova, M., Nagyova, G., Kuchar, D., Bacova, H., Minarcikova L., Bunka, F. (2015). The effect of composition of ternary mixtures containing phosphate and citrate emulsifying salts on selected textural properties of spreadable processed cheese. *International Dairy Journal*, 44: 37-43.

Sales, R.L., Costa, N.M.B., Monteiro, J.B.R., Peluzio, M.d.C.G., Coelho, S.B., Oliveira, C.G.d., Mattes, R. (2005). The effects of peanut, safflower, and olive oil on body composition, energy metabolism, lipid profile and food intake of eutrophic, normolipidemic subjects. *Revista de Nutrição* 18(4), 499-511.

Santos, B., Resurreccion, A., Garcia, V. (1989). Quality Characteristics and Consumer Acceptance of a Peanut-Based Imitation Cheese Spread. *Journal of food science*, 54(2), 468-471.

SAS, S. (2008). STAT 9.2 User's Guide. Version 9.2. Cary, NC: SAS Institute. Inc.

Schmidt, D. (1982). Electron microscopy of milk and milk products: problems and possibilities. *Food Structure*, 1(2), 6.

Shaw, M. (1984). Cheese substitutes: threat or opportunity. *Journal of the Society of Dairy Technology*.

Solowiej, B., Cheung I.W.Y., Li-Chan, E.C.Y. (2014). Texture, rheology and meltability of processed cheese analogues prepared using rennet or acid casein with or without added whey proteins. *International Dairy Journal*, 37, 87-94.

Tamime, A., Kalab, M., Davies, G., Younis, M. (1990). Microstructure and firmness of processed cheese manufactured from Cheddar cheese and skim milk powder cheese base. *Food Structure*, 9(1), 4.

Tamime, A., Muir, D., Shenana, M., Kalab, M., Dawood, A. (1999). Processed cheese analogues incorporating fat-substitutes 2. Rheology, sensory perception of texture and microstructure. *LWT-Food Science and Technology*, 32(1), 50-59.

Tamime, A.Y. (2011). Processed cheese and analogues. John Wiley & Sons.

Tamime, A.Y., Robinson, R.K. (1999). *Yoghurt: science and technology*, Woodhead Publishing.