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Study on Processed Cheese Analogue by Replacing Milk Fat with Healthier Refined Vegetable Oils and Whey Polymerized

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Abstract

This study was designed to produce functional spreadable processed cheese analogue by replacing milk fat with healthier refined vegetable oils (Palm Oline / Rice Bran Oil), incorporating whey protein concentrate (WPC) or its polymerized form (WPP). Three different types of edible oil BO, RBO and PO) were used as a source of fat in the production of full fat spreadable processed cheese analogues. A partial substitution of cheese base by either whey protein concentrate (WPC) or its polymerized form (WPP) was also conducted in each blend. Body and texture of spreadable processed cheese analogue contained PWP regards of edible oils had higher score than those contained WPC. From nutrition and health points of view it is well observed that substitution of milk fat by edible oils are in increase. The adding rice bran oil (RBO) had significant impacts on spreadable processed cheese analogues composition and quality. The adding RBO increased, the properties. flavor, body, texture, color and appearance were improved. The change in physicochemical properties was strongly influenced by the composition and structure of , whey polymerize- pureed cauliflower fat- matrix, the improvement in texture properties manifested by higher meltability, lower hardness and adhesiveness. The functional processed cheese with polymerize- White Cauliflower pureed and rice bran oil had excellent acceptability. Under current study the replacing of milk fat by butter oil, Rice bran oil or Palm oil in the spreadable processed cheese analogues were evaluated. Depending on the gained data we can conclude that the antioxidant activity and oxidative stability of cheese samples are highly affected by the type and percent of fat in the final product.

Keywords: spreadable processed cheese analogue; rice bran oil; palm oline; cauliflower; whey protein polymerized

Introduction

In recent years, the areas of research of nutritionists and food companies have responded to consumers demand and preference. They have begun to look at food not only as a source of energy but also for health benefits (Giriet al., 2015). Processed cheese is a useful vehicle for such studies because the sensory profiles and functional properties of commercial samples of processed cheese spreads (full- and low-fat) have already been characterized. Moreover, in the 20 year period to 1994, production of processed cheese in Europe, North America, New Zealand and Japan has increased by 20%, European countries account for the majority of international exports (Muiret al., 1999). Recently, processed cheese spreads have become a popular variety of processed cheese products science it has a wide range of food applications and it became an important part of the cheese market. In Egypt, the production of processed cheese products is in a continuous increase and has received much attention (Caric and Kalab, 1993; Calvoet al., 2007 and Dave, 2012). Imitation cheeses or cheese analogues are cheese-like products in which milk fat, milk protein or both are partially or wholly replaced by non-milk-based components to produce a specific cheese variety. They are manufactured by blending various edible fats/oils, proteins, other ingredients and water into a smooth homogenous blend with the aid of heat, mechanical shear and emulsifiers. The market of analogues has grown recently due to their simplicity of production, and the substitution of lacteal ingredients by cheaper vegetable ones, factors that allow for a reduction in product manufacturing costs. Regularly, the formulation of processed cheese can be done by blending different cheese types with different degree of maturation, flavoring into smooth homogeneous blend with the aid of heat, mechanical shear and emulsifying salts (Cunha et al., 2013 and Awadet al., 2014). Recently, because of both economic reasons and the increase of consumer's awareness on the impact of food on health the use of partially or fully replacement of natural cheeses with several dairy or non-dairy ingredients have been used to produce processed cheese-like (cheese analogs) products (Stoon, 2002 and Solowiej, 2007 and Awadet al., 2014). Regarding the water phase, either rennet or acid caseins or their combination are reported to be good sources of protein in production of processed cheese imitations. That because of their functional characteristics to giving food products a suitable structure, consistency, fat emulsifying properties, whipping ability and bland flavor (Solowiej, 2007, Solowiejet al., 2014 and Lima et al.,2022). Using of whey protein preparations has gained much attention in recent years in dairy industries. Their presence in food and dairy products can contribute to the essential savings of basic material and to the improvement of rheological properties of processed cheese analogue. Moreover, the application of low protein concentrates, to obtaining processed cheese analogues, makes it possible to reduce production costs (Solowiejet al., 2008&Atik and Huppertz. 2023). Studies on the effect of whey protein polymers produced by a single or double heating process on the physical properties of processed cheese analogues. Using whey protein polymers produced by double heating 23% of the rennet casein protein can be replaced and produce a process cheese analogue with similar texture properties and meltability (Mleko and Foegeding, 2001). Therefore, the main objective of this study is to develop a novel functional spreadable processed cheese analogues.

Materials And Methods

1.Materials

a.Milk and whey protein concentrate

Fresh skimmed buffalos' milk obtained from the herd of the Faculty of Agriculture, Cairo University, Giza, Egypt was used to produce acid and rennet caseins Whey proteins concentrate (WPC: protein 80%, Lactose 4%, Ash 3%, Fat 4%, Moisture 3.5%) was supplied by Agri- Mark, Inc., USA.

b.Edible fats and oils

Buffalos' butter was obtained from Cream after churning process in our lab. Then, it was converted to butter oil by melting at 60°C for 30 min. and stored at 5°C until used.Palmolein oil was purchased from Arma Company for Food Industries.

Rice bran oil (Free from cholesterol and contains 200mg/100g oil of Oryzanol) produced by the THAI edible oil Co., LTD, Thailand was purchased from Egyptian local market. According to suppliers, it was extracted from selected bran of brown rice and germ. Also, it contains Vitamin E, phytosterols and Gamma Oryzanol as natural antioxidant materials.

c. Emulsifying salt

S¬9s special obtained from JOHA BK Ladenburg, Germany was used as an emulsifying salt.

d. Rennet

A single strength liquid calf rennet was obtained from Dairy unit, Dairy science Department, Faculty of Agriculture, Cairo University and it was added to the milk at rate of 1.5 ml Kg-1 milk.

e. Starter Culture

Freeze-dried lactic culture for Direct Vat Set (YC-X11, thermophilic yoghurt culture Yo-Flex®) was obtained from Misr Food Additives Company, Giza, Egypt and it was used as a starter culture.

f. Sodium chloride

A commercial fine grade sodium chloride salt was obtained from El-Nasr saline's Co., Alexandria, Egypt.

2. Methods

a. Preparation methods

1. Preparation of protein matrix

Two kinds of casein curd were prepared as follow:

I- Milk was pasteurized (72°C /15s), then cooled at 40°C then the manufacturing steps were completed according to traditional method for making Ras cheese. This curd was curd (1) and it contains (41.89% TS, 1.93% fat and 4.607% F/DM). The manufacturing steps were illustrated in fig. (1) Hofiet al. (1970).

II- Green curd (curd 2) was manufactured by following technique the coagulation by rennet only and when the occurred coagulation the curd was cutting and wheydrainage. After that the cheese was put into the fridge at 5°C untilto used. This curd was curd 2 that contains (28.83% TS, 0.90% fat and 3.171% F/DM).

Milk
↓
Heating at 72°C/15 sec.
↓
Cooling at 40°C
↓
Addition of 1.5% starter and riepening for 30 min.
↓
Addition of standard rennet (1.5ml/Kg milk)
↓
Curd cutting and scalding by raising the temperature to 45C/50 min.
↓
Whey drainage
↓
Hooping and pressing

Figure 1: Flow chart of the processing of curd (1).

2. Preparation of whey protein concentrate Polymerized

Polymerized whey protein solution (WPP) was prepared from WPC (protein 80%) following the method described by Sołowiejet al. (2015) the 4% WPC solution was prepared and kept overnight at 4ºC for full hydration. The hydrated solution was heated at 80º C for 50 min., cooled at room temperature and then the pH was adjusted to 6.2 with 40% citric acid and storage at Frigidaire until used.

3. Preparation of buffalo butter oil

Butter oil preparation was performed according to Fatouhet al. (2003) with some modifications. buffalo butter were melted separately at 50 °C instead of 60 °C, and the top oil layer wasdecanted and filtered through glass wool. The oil was then re-filtered under vacuum to obtain clearbuffalo butter oil.

b. Experimental methods

1.Processing of different spreadable processed cheese analogues

The full fat, half fat and low fat spreadable processed cheese analogues were prepared under the guide lines recommended by the Egyptian Organization for Standardization and quality. They were formulated under the regulations appeared in the Egyptian Standers (ES: 1132-2/2005) for processed cheese with vegetable oils and fats parts 1 and 2 as follows: 59% moisture, 41%TS, 18.45% fat and 45 F/DM for full fat, 69% moisture, 31%TS, 7.75% fat and 25 F/DM for half fat and 71% moisture, 29%TS, 4.35% fat and 15 F/DM for low fat (fig.2).

The processing of spreadable processed cheese analogues was done under three categories in this study as follows:

a. **Processing of different spreadable processed cheese analogues as affected by Edible fat type.**

Nine different blends of spreadable processed cheese analogue were manufactured in which they are different from each other in the source of fat (butter oil, palmolein or rice bran oil) or its percent (Full fat, half fat or low fat). The ingredients (g/Kg blend) used are illustrated in (table 1). Each blend was processed in a double jacketed pan using a direct steam for heating at 85-90ºC for 5 min. with continuous mixing at 1400 rpm. The hot semi-fluid processed cheese analogue was poured into plastic cups with screw, and then cooled rapidly. Samples from each blend were divided into three groups. The first one was analyzed as fresh sample, the second was stored at 5ºC for three months and the third was kept at 25ºC for three months as storage conditions before they were analyzed figure.(2).

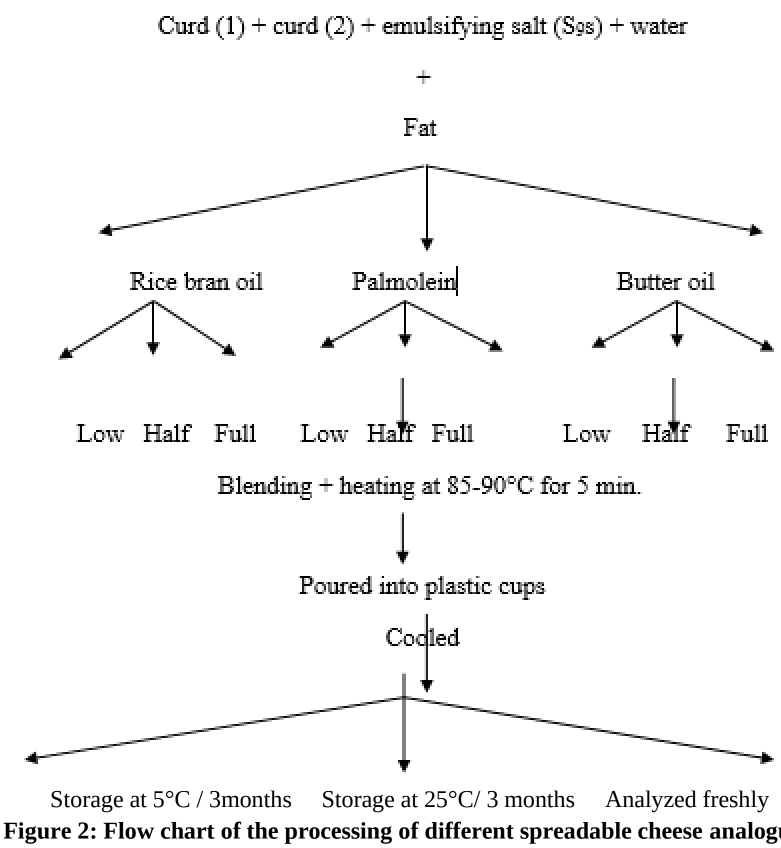

Figure 2: Flow chart of the processing of different spreadable cheese analogues.

Spreadable processed cheese blend	Ingredient (g/Kg blend)					
	Curd (1)	Curd (2)	Emulsifying salt (S_{9s})	Salt	Fat	Water
Full fat	250	305.5	30	10	176.5	228.0
Half fat	250	330.4	30	10	69.2	310.4
Low fat	266	357.0	30	10	34.6	302.4

Table 1: Blends composition of the spreadable processed cheese analogues used in the study.

a. Processing of full fat spreadable processed cheese analogues containing RBO as affected by partial substitution of protein base with WPC or WPP.

Six different blends of full fat spreadable processed cheese analog were manufactured. Each two of them contained the same type of edible fat or oil (butter oil, palmolein or rice bran oil) but they differ from each other in either the addition of WPC or WPP as partial substitution from the protein base. The ingredients (g/Kg blend) used is tabulated in Table (2).

Spreadable processed cheese blend	Ingredient (g/Kg blend)						
	Curd (1)	Curd (2)	WPC or WPP	Emulsifying salt (S_{9S})	Salt	Fat	Water
Full fat	150.0	357.0	295.0	30.0	10.0	17.54	24.81

Table 2: Blends composition of the full fat spreadable processed cheese analogues with WPC or WPP.

Curd (1): The curd was made by Ras cheese method.

Curd (2): Green curd

WPC: Whey protein concentrate.

WPP: Whey protein polymerized.

Emulsifying salt: (S9special).

c. Analytical methods

1. Chemical composition and pH

Moisture and ash contents were determined as described by AOAC (1990). Total nitrogen and fat contents were determined as mentioned by Ling (1963). The pH values were measured by using pH meter: PTI-15, Aque chemical Co., England.

2. Minerals determination

Minerals were determined in the Regional Centre for Food and Feed, Agricultural Research Centre, Giza, Egypt. The method described in (AOAC, 2003) was applied. Fe, Zn, Ca and Mg were measured by Atomic Absorption spectrophotometer (Model: GBC 932AA). Na and K were estimated by clinical flame photometer 410◦C.

4. Fatty acids profile analysis

For fatty acids relative distribution analysis of different fats the fatty acids methyl esters were produced according to AOAC (2000).

5. Oxidative stability

The thiobarbituric acid (TBA) value′s determination was done according to method described by Keeny (1971).

6. Rancimat test

Rancimat was used, which calculated OSI based on incubation time period. The OSI at 110°C was determined according to AOCS Official methods Cd 12b-92. A metrohm743 (Herisev, Awizerland).

a. Acid degree value

The method recommended by (AOCS, 1995).

b. Peroxide value (PV) Measurement

The method recommended by (AOAC, 1990).

c.Total volatile fatty acids (TVFA) analysis

The Total Volatile Fatty acids (TVFA) of cheese were determined by the direct distillation method according to Kosikowski (1986).

d.Determination of Dienes content

Conjugated linoleic acids were estimated Spectrophotometrically according to the method of A.O.A.C. (1995).

e. Determination of Thiobarbituric acid (TBA) value

TBA was determined according to the method of Keeny (1971).

7. Amino acids profile analysis

The amino acid profile cauliflower puree was determined using methods described by Speckmanet al. (1958).

8. Antioxidant activity

Antioxidant activityWas determined according to the method of (Mordi and Akanji, 2012).

9. Physical and rheological analysis

a. Determination of meltability

Meltability of cheese samples was measured in duplicate. The method modified by Savelloet al. (1989).

b. Determination of oil separation

The oil separation index (OSI) of cheese samples was determined according to the method outlined by Thomas et al. (1980).

c. Determination of viscosity

The apparent viscosity, consistency coefficients and flow behavior indices of the spreadable processed cheese analogue samples were evaluated according to (Brookfield manual, 1998).

a. Determination of texture profile analysis (TPA)

The tests were carried out in quadruplicate according to Rapacci (1997), as described by Cunha and Viotto (2010).

b. Determination of color characteristics

Instrumental color evaluation was performed using the Color Quest II model, Hunter lab colorimeter (Hunter Associates laboratory, Inc., Reston, VA, USA) were obtained (Wadhwani and McMahon, 2012).

10. Microstructural analysis

Microstructure of the cheese samples was examined with a SEM Jeol model JXA-840A; (Japan), electron probe micro analyzer using a magnification of 4,000X (Walsh et al., 2010).

11. Sensory analysis

Different spreadable processed cheese samples were evaluated for their sensory attributes by ten trained panelists. According to their awareness on the properties of processed cheese characteristics, they were carefully selected among the staff members of the Dairy Science Department, Faculty of Agriculture, Cairo University, Egypt and the Food technology Institute, Giza, Egypt. Each panelist was asked to evaluate each cheese sample for four sensory attributes; flavor, body and texture, appearance and color out of 40, 40, 10, and 10 score points, respectively, Scheme of Mayer (1973).

12. Statistical analysis

The resultant data of the three replicates of each treatment and control were statistically analyzed and subjected to varieties of analysis and Duncan's test as well as average and standard error following Minitab INC. (2005).

Results And Discussion

1.Incorporation of refined Rice Bran Oil and/or Palm Olein in the spreadable processed cheese analogues

a. Characterization of edible oils

Fatty acids composition plays a major in relation to relation about oxidation. The rice bran oil (RBO) as it is expected to improve the oxidation stability of the blends (oil) because it contains natural antioxidants. Palm Olein oil is the most used oil for frying, because its high saturated fatty acids and excellent stability oil. All edible oils used in the study were evaluated for their fatty acid composition, oxidative stability, acid value and peroxide value. The RBO had the highest % of poly unsaturated fatty acid followed by Palm olein and butter oil It is clear that Polyunsaturated fatty acid / saturated fatty acid ratio (known as polyene index) was the highest for RBO followed by Palm olein and butter oil. The Polyunsaturated fatty acid / saturated fatty acid was usually taken as a measure of the extent of Polyunsaturation of oil and used an indicator for the tendency to undergo auto oxidation (Srivastava and singh 2015). The rice bran oil has a higher content of MUFAs(41.77). According to typical American diet SFA: MUFA: PUFA was 33: 44: 23. The American Heart Association recommented a fatty acid balance of approximately 1: 1.5: 1 ratio of SFA: MUFA: PUFA (Hayes, 2002). Also, the saturated, monounsaturated and polyunsaturated fatty acids in RBO are in the ratio of approximately 1: 2.2: 1.5 and the major fatty acid composition are most influences.

2.Incorporation of whey protein concentrate or its polymerized form in the full fat spreadable processed cheese analogue with different types of editable oils.

Numerous treatments are available to improve whey protein functionality including enzymatic hydrolysis, fractionations, and heat treatments (foegedinget al., 2002). Heating of whey proteins at PH values greater than 6.0 leads to the formation of soluble polymers of disulfide linked protein monomers (Jiangwanget al., 2018).

a. Chemical composition and pH of fresh spreadable processed cheese analogues containing WPC or PWP

The chemical composition of spreadable processed cheese analogues made with different types of edible oils and either WPC or PWP is shown in Table (3). Total solids content ranged from 41.12% to 41.55% meeting and the F/DM ratio of processed cheese ranged from 44.13 to 45.14 which satisfy the legal standard (Egyptian standards, 2005). Also, there were significant differences in ash and total protein percent ranged from 3.41 to 4.43% and 14.07 to 15.27% respectively. In other words, TS% and fat% as well as F/DM ratio of treatments varied in narrow range but with no significant difference ($P<0.05$). However, a significant difference between T6 contained PO and PWP and each of T2 (contained RBO and WPC) and T5 (contained RBO and PWP) was detected for TP%. Data obtained also show a significant effect of protein type on ash% content of T1and T4 on one hand and T3 and T6 on the other hand. Nogueiraet al. (2018). They showed that the pH value of the spreadable processed cheese was significantly affected ($P < 0.05$) by the type and proportion of the two emulsifying salts (commercial; Monopotassium phosphate MKP). Cheeses containing only monopotassium phosphate exhibited the lowest pH value compared other samples.This due to the ability of anhydrous monopotassium phosphate to promote pH decreases in the cheese system. Other authors have reported pH values of processed cheese spreads based on specific emulsifying salts (Kapoor and Metzger, 2008).

Regarding the pH values there were no remarkable differences among all spreadable processed cheese analogue samples.

Increased in higher pH, whereas decreased alongside with addition of demineralized whey powder at pH 6.0-7.0

Treatment	TS (%)	Fat (%)	F/DM%	TP (%)	Ash (%)	pH
T_1	41.26±0.251^a	18.27±0.252^a	44.27±0.876^a	14.42±0.478^{ab}	4.43±0.135^a	6.2200±0.0100^a
T_2	41.26±0.150^a	18.53±0.208^a	44.92±0.662^a	14.07±0.341^b	4.19±0.055^{ab}	6.2600±0.0100^a
T_3	41.33±0.286^a	18.40±0.361^a	44.52±1.155^a	14.47±0.529^{ab}	4.13±0.112^b	6.2300±0.0100^a
T_4	41.21±0.221^a	18.27±0.252^a	44.33±0.720^a	14.41±0.715^{ab}	3.83±0.071^c	6.0000±0.0100^b
T_5	41.12±0.137^a	18.57±0.153^a	45.14±0.421^a	14.20±0.254^b	4.04±0.178^{bc}	6.2500±0.0100^a
T_6	41.55±0.004^a	18.33±0.351^a	44.13±1.056^a	15.27±0.836^a	3.41±0.188^d	6.2000±0.0100^a
LSD	NS	NS	NS	1.002	0.236	

Table 3: Chemical composition of full fat spreadable processed cheese analogues with different edible oils and WPC or PWP.

T1: full fat butter oil with WPC, T2: full fat rice bran oil with WPC, T3: full fat palm Olein with WPC, T4: full fat butter oil with PWP, T5: full fat rice bran oil with PWP, T6: T3: full fat palm Olein with PWP.

Different superscripts at the same column are significantly different ($P<0.05$).

WPC: Whey proteins concentrate **PWP: polymerized Whey protein**

NS: Non significant

Data showed the no significantly difference ($P\geq0.05$) between all samples regardable type of edible oil or whey protein products (WPC or PWP). These results are in conformability with those (Abdeenet al., 2018).

a. Oxidative stability of fresh spreadable processed cheese analogues containing with different edible oils and WPC or PWP

The extent of lipolysis as assessed by AV was determined and illustrated (Table 14) for all spread cheese analogue samples under this study. According to standard codex (2013) the AV must be lower than 0.6mg/g fat. The results showed that all fresh cheese samples were within the allowed level. It can be seen that the samples containing RBO had the highest AV while its value was the lowest for samples with BO, among all other samples. Regarding the effect of protein type, there was a significant effect between T3 (containing WPC) and T6 (containing PWP). The oxidative stability of fats is influenced by the degree of polyunsaturation. The fats that are more unsaturated are oxidized more quickly than those less unsaturated. On the other hand, among all fatty acids, polyunsaturated fatty acids are highly labile molecules and susceptible to oxidation processes giving rise to free radicals, hydroperoxides and polymers, which might lead to a loss of technological and healthy of interesterified fats (Wirkowskaet al., 2012). It is well known that PV is considered the most widely chemical method used to detect the auto oxidation of edible fats and oils. However, peroxides which measures only the primary products (peroxides) of fats and oils oxidation are subjected to rapid destruction. It can therefore measure only the current or recent oxidation (Agbaire, 2012). The lowest PV was recorded to be for cheese samples with BO among all other samples while the highest PV was for the two samples containing RBO (T2 and T5) with no significant difference between them because of the type of protein. The peroxide value of palm olein blends with other edible oils (canola oil, sunflower oil and soybean oil to increase with the storage time and temperature. The initial PV was found to have occurred around 2.5 to 5 meq O2/kg oil which indicates a relatively good quality of these oils. The initial value and after 3 weeks the PV for palm olein-canola blends was found to be almost the same. This indicates that the natural antioxidants in both palm and canola oil that hinder the oxidation process. They also indicated that storage at ambient temperature caused the PV to increase rapidly due to the contact with air and light (Siddiqueet al., 2010 and Zhao et al., 2023). Regarding the TVFA it can be observed that there is a significant difference in its amount between all cheese samples. Slight significant differences were also observed between T1 and T4 and between T3 and T6 which they are differ from each other's only on the type of protein. The effect of protein type on the TVFA content was not significant between T2 and T5. Table (14) also shows the percent of conjugated dienes in cheese samples as affected by both the type of fat and protein. The minimum of 0.02% was in T6 (containing PO and PWP) and the maximum of 0.080% was in T1 (containing BO and WPC). Difference in conjugated dienes percent between cheese samples with BO (T1 and T4) was significant which is reflecting the effect of protein type this results that agreement with (Elaaser, 2010). Zeb and FareedUllah (2016).Reported that the reactivity of TBA with several reactive substances, a more widely accepted terminology called thiobarbituric acid reactive substances (TBARS). The TBARS is now considered as a standard marker for the lipid peroxidation. It was found that the primary oxidation products are further oxidized to form secondary and tertiary oxidation products because of their effect on food quality and safety. One of the important oxidation products is known as malondialdehyde (MDA) and reacted with TBA which resulting in colour compound, which can be determined spectrophotometrically at 532 nm. Hence the TBA value is the measure of antioxidant and that there is no standard requirement for its value in cheese fat. The TBA values in spreadable processed cheese analogues from different treatments are shown in Table (4). The minimum of 0.011 in T2 and a maximum of 0.019 in T5 were observed and representing the only significant difference among all other compared to all other cheese samples. This may be due to the presence of SH-groups as explained by Elaaser(2010). They said that heating of cheese mass during processing induced denaturation of the occurring whey proteins present in cheese blends producing free SH-group which can act as an antioxidant and protect cheese fat from oxidation. Bierzuńska andCais-Sokolińska (2018). In¬creasing the proportion of whey proteins in yoghurt increased its antioxidant potential. The addition of PWP had a greater effect on the increase in DPPH and FRAP values than adding WPC80 (P<0.05).

Treatment	AV	PV	TVFA	Conjugated Dienes	TBA
T_1	0.23 ± 0.020^{d}	0.29 ± 0.015^{d}	19.16 ± 0.062^{b}	0.08 ± 0.006^{a}	0.013 ± 0.002^{ec}
T_2	0.58 ± 0.010^{a}	0.54 ± 0.020^{a}	15.05 ± 0.252^{d}	0.04 ± 0.005^{c}	0.011 ± 0.002^{c}
T_3	0.42 ± 0.020^{c}	0.43 ± 0.020^{b}	16.53 ± 0.316^{c}	0.03 ± 0.005^{de}	0.014 ± 0.003^{bc}
T_4	0.22 ± 0.010^{d}	0.37 ± 0.021^{c}	20.03 ± 0.089^{a}	0.06 ± 0.007^{b}	0.015 ± 0.004^{abc}
T_5	0.55 ± 0.020^{a}	0.53 ± 0.031^{a}	15.32 ± 0.195^{d}	0.03 ± 0.003^{cd}	0.019 ± 0.001^{a}
T_6	0.46 ± 0.031^{b}	0.41 ± 0.015^{b}	12.90 ± 0.095^{e}	0.02 ± 0.006^{e}	0.017 ± 0.002^{ab}
LSD	**0.0351**	**0.0373**	**0.3428**	**0.0091**	**0.0048**

Table 4:Oxidative stability of spreadable processed cheese analogues with different edible oils and WPC or PWP.

T1: full fat butter oil with WPC, T2: full fat rice bran oil with WPC, T3: full fat palm Olein with WPC, T4: full fat butter oil with PWP, T5: full fat rice bran oil with PWP, T6: T3: full fat palm Olein with PWP.

Different superscripts at the same column are significantly different (P<0.05).

WPC: Whey proteins concentrate **PWP: polymerized Whey protein**

TBA: measured as monoaldhyed.

a.Meltability and apparent viscosity of spreadable processed cheese analogues with different edible oils and PWP or WPC.

Data presented in Table (5) show the effect of WPC or PWP in the meltability and apparent viscosity of produced spreadable processed cheese analogue samples contained BO (T1 and T4), RBO (T2 and T5) or PO (T3 and T6). The presence of PWP significantly decreased the meltability of cheese samples when compared to samples contained WPC. This was in parallel with those reported by (Mleko and Foegeding, 2001) who reported that the increase in whey protein polymers decreased meltability. The apparent viscosity is also affected by whey protein type. PWP significantly decreased viscosity of cheese samples than those contained WPC when the same type of edible oil used. Also, the type of edible oil added has a significant effect on viscosity which can be ordered dissentingly as follows T1>T2>T3 for samples contained WPC and T4>T5>T6 for samples contained PWP. Sołowiejet al. (2010). Indicated that the meltability of processed cheese analogs decreased with increased of acid casein or WPC concentration but still melting properties were very good. Abdeenet al. (2018) indicated that the substitution of young and aged Ras cheese with camel cheese based caused decrease in the meltability. The meltability was closed and positively correlated with the textural characteristic of cohesiveness in processed cheese. It can be predicted that meltability is correlated to the state of the casein in cheese acidification and proteolysis. In addition, other factors may be important in determining the extent of emulsification and melting properties of processed cheeses. Also, they concluded that low fat processed cheese spread with good meltability, desired body and texture characteristics, and improved spreadability can be prepared by using camel milk retentate with Ras cheese based at least 25-50%. Melting of processed cheese analogue or imitation is arguably its most important functional properties (Hennellyet al., 2005). They indicated that the meltability of processed cheese analogue decreased significantly with increased protein concentration. Analogues prepared with cid casein and samples solely from 11% rennet casein were characterized by good melting properties whereas cheese analogues prepared rennet casein had poor meltability. Cheese analogues made using 10% AC and 1% WPI or 10% RC and 1% WPC 80 exhibited the highest meltability whereas those made of 10% RC with 3% WPI or WPC 80 exhibited lowest meltability. They observed decrease processed cheese analogue meltability it’s likely the result of interaction between K- casein and B-light resultant structure created being created jointly by the casein and whey protein or by whey protein joining the structure formed solely by casein. Higher temperature increases interactions (cross-linking) between whey proteins and casein, and as a consequence, decreases the meltability of the final product. The spreadable processed cheese analogue contained full fat (RBO) and PWP had higher texture parameters that that of contained full fat (RBO) and WPC. These results showed that when emulsion was stability, it apparent viscosity had the highest value and reported that ES in results increased protein hydration and formation of continuous protein network structure, causing an increase in decrease of emulsification and viscosity (Jingwanget al., 2018). The viscosity of yoghurt containing RBO was significantly increased as RBO% increased either fresh or stored with storage period up to 7 days. Also, there is no significant differences (p>0.05) in hardness, therefore the addition of nano-emulsion containing RBO did not affect the texture of frozen yoghurt, consequently the higher instrumental hardness of frozen yoghurt can be attribute to their lower overruns (Abbas et al., 2017). Various chemical and compositional factors have an effect on the functional properties of processed cheese and processed cheese analogues. One of these factors is the viscosity. Also, they showed that the measurement of processed cheese viscosity can help characterize meltability of the final product. Samples using 10% AC with the addition of 2 or 3% WPC80 were more viscous than those prepared using 10% RC and 2 or 3% WPC80. Whereas processed cheese analogues made using 10% AC and 1% WPI or 10% RC and 1% WPC 80 exhibited the lowest viscosity. This phenomenon also may be related to the calcium content of RC, AC, WPC 80 and WPI. Also, low protein and calcium contents result in poor viscosity product which as agreement with Sołowiejet al (2014). The viscosity of PWPI was higher than that of PWPc under the same conditions. This might be bredominantly due to the viscosity of soluble whey aggregates which depend on heat treatment as well as on the nature and relative composition of the WPI or WPC in the suspension Jingwanget al. (2018). The viscosity of camel milk stirred yoghurt increased with the increased polymerized whey protein. The 8% polymerized whey protein has maximum viscosity as compared to 2%, 4% and 6% polymerized whey protein. However, effect of polymerized whey protein isolates on quality of stirred yoghurt made from camel milk Sakandaret al. (2014). Li and Guo (2006). They indicated that the incorporation of PWP significantly (P < 0.001) increased the viscosity (by 80%) and decreased the syneresis (by 25%) of goat milk yogurt.

Treatment	**Meltability (cm)**	**Apparent viscosity (Pa.s)**
T1	3.6±0.3^{c}	47.16±0.35^{a}
T2	3.0±0.1^{d}	36.50±0.27^{b}
T3	5.3±0.3^{a}	25.58±0.30^{c}
T4	3.1±0.1^{d}	24.40±0.40^{d}
T5	2.7±0.1^{e}	20.26±0.22^{e}
T6	4.9±0.1^{b}	16.30±0.34^{f}
LSD	**0.3**	**0.57**

Table 5: Meltability and apparent viscosity of spreadable processed cheese analogues with different edible oils and PWP or WPC.

T1: full fat butter oil with WPC, T2: full fat rice bran oil with WPC, T3: full fat palm Olein with WPC, T4: full fat butter oil with PWP, T5: full fat rice bran oil with PWP, T6: T3: full fat palm Olein with PWP.

Different superscripts at the same column are significantly different (P<0.05).

WPC: Whey proteins concentrate **PWP: polymerized Whey protein**

a.Texture profile analysis (TPA) of fresh spreadable processed cheese analogues with different edible oils and WPC or PWP.

Texture profile analysis of different samples is shown in table (6). Data presented in Table (6) indicated that all the texture profile that increase by PWP than WPC except for springiness criterion, other texture parameters of T5 followed by T2 exhibited significantly higher values than the others which may be due to the different types of proteins. In the texture analyzer, it is the peak force during the first compression (force required for a pre-determined deformation). Hardness of pro¬cessed cheese, in particular, is an attribute directly correlates with the moisture content, fat content, pH, emulsifying salt and the type and properties of natural cheese incorporated in the blend. The increase in hardness values of cheese samples can be attributed to the decrease in moisture content. Gustaw, (2007) observed that hardness of the yoghurt with polymerized WPI addition was four times higher than the one recorded for the control samples. The addition of whey proteins aggregates probably caused an increase in density of random whey proteins aggregates in yoghurt. Wang et al. (2018) indicated that as level of PWP increased, the hardness of yogurt increased from 81·63 ± 4·10 to 454·17 ± 34·76 g. The addition of PWP resulted in a more rigid gel structure in yogurt due to the formation of aggregates via interactions between PWP and casein micelles. Shamsia and El-Ghanam (2017) indicated that the hardness of processed cheese analogue made from ricotta cheese was significantly increased with ricotta cheese. Fox et al. (2017) reported that the increase of whey protein content increase the hardness of cheese. Solowiej (2007) observed that hardness of processed cheese analogues obtained on the base of acid casein was of very high pH 4.5-5.0, however it decreased significantly with the increase of pH values. Addition of whey products to cheese analogues causes an increase in their hardness, viscosity and meltability. Abbas et al. (2017) showed the values of adhesiveness on the negative side for processed cheese analogues that contain ricotta cheese with increasing trend as the ratio of ricotta cheese increased. Also, they observed that no significant decrease in the cohesiveness values with the increase of ricotta cheese ratio to fresh and stored processed cheese. Also, the data revealed that addition of ricotta cheese led to significant decrease in gumminess values in both fresh and stored cheese. In the tex¬ture analyzer, it is the work necessary to pull the compressing plunger away from the sample (Work required to overcome the sticky forces between the sample and the probe). Adhesiveness is a negative value, as it increases in the negative side as the ad¬hesiveness is greater and the sample is sticky. Also, Increase in adhesiveness of processed cheese food with added WPC. The increase in adhesiveness may be attributed to the increasing extent of breakdown of protein during storage. In the texture analyzer, it is the height that food recovers. The springiness of cheese increased. But the cohesiveness, unlike other rheological properties, decreased for both the cheese products The decrease in cohesiveness may be due to increase in pH values. The pH increases, solvation of protein chains increases which reduces the free water. Therefore hardness increases and cohesiveness decreases Kumar (2012). Springiness (mm) or elasticity of cheese is defined as a degree at which the cheese samples goes back to its original shape after partial compression between tongue and palate (Meullentet al 1997). Chatziantoniouet al (2015). Indicated that spreadable processed cheese whey with an increase fat content result in softer and more cohesive. The disruption of the continuity of the protein matrix by fat leads to a more soft texture, but the flocculation or partial aggregation of fat droplets could be the cause of an increase in cohesiveness and springiness. Also, they reported that an increased stringiness in block-type cheeses of high fat content. The addition of whey concentrates (WPC 35 and WPC 65) processed cheese analogs produced harder cheeses than cheese analogs obtained solely from AC. Cheese analogs with the addition of 3 % WPC 35 exhibited the highest hardness. Reduction in the level protein results in a decrease in hardness. Cheese analogs obtained with addition of whey protein concentrates were much more cohesive than those contained AC, The cohesiveness of cheese decreased with decreased fat content. Cheese analogs with 3 % of WPC addition presented particulate, much more unhomogenous network. This structure was probably responsible for decreased cohesiveness Sołowiejet al. (2010). The gumminess of both the cheese samples was increased. As gumminess is directly correlated to hardness, this higher increase in case of control processed cheese can be attributed to the significant increase in hardness of control cheese. The chewiness values tended to be decreased with the addition of successive amounts of ricotta cheese in either fresh or stored processed cheese. The displacement of dried skimmed milk by ricotta cheese with different ratios (9.22-27.7) had no considerable influence on the texture characteristics of the prepared processed cheese Abbas et al. (2017). The hardness, adhesiveness, cohesiveness, springiness, gumminess, and chewiness of low fat processed cheese spread decreased with the increase bases camel milk retentate with Ras cheese. The decrease in hardness is accredited to early variation in the texture which is associated to the proteolysis of casein network, increasing protein hydration and solubilized of colloidal calcium phosphate. The variations in hardness should be related partially to its moisture content Abdeenet al. (2018). Body and texture of spreadable processed cheese analogue contained PWP regardes of edible oils had higher score than those contained WPC. This may due to the binding of PWP to the micelle surface favors the formation of bridges between the casein particles leading to a narrow pored mixed casein/PWP network, thus results in improved consistency and less syneresis Li and Guo (2006). Sołowiejet al (2014). Showed that the processed cheese analogues using AC or RC, plus 1, 2, 3% WPC 80 or WPI was producing hardness, adhesiveness and viscosity generaly, increased and meltabilitydencreased with protein concentration.

Treatment	Hardness (N)	Adhesiveness (mJ)	Springiness (mm)	Cohesiveness (ratio)	Gumminess (N)	Chewiness (mJ)
T_1	13.03±0.306^{e}	2.60±0.459^{f}	13.49±0.017^{c}	0.95±0.015^{e}	2.67±0.306^{e}	33.69±1.20^{f}
T_2	20.65±0.850^{b}	6.86±0.634^{b}	9.60±0.247^{e}	1.26±0.086^{d}	12.60±0.800^{b}	172.18±1.60^{b}
T_3	13.20±0.265^{e}	3.71±0.078^{e}	13.49±0.015^{c}	1.10±0.092^{de}	3.37±0.321^{e}	46.51±2.82^{d}
T_4	16.70±0.458^{d}	4.51±0.138^{d}	16.35±0.317^{b}	1.89±0.076^{c}	4.87±0.252^{d}	42.80±0.29^{e}
T_5	25.52±0.257^{a}	9.16±0.393^{a}	12.26±0.363^{d}	3.40±0.276^{a}	15.43±0.416^{a}	184.23±1.07^{a}
T_6	18.13±0.351^{c}	5.37±0.262^{c}	16.94±0.055^{a}	2.32±0.256^{b}	5.90±0.458^{c}	51.22±0.41^{c}
LSD	**0.8238**	**0.6742**	**0.3960**	**0.2939**	**0.8232**	**2.6539**

Table 6: The texture profile analysis (TPA) of spreadable processed cheese analogues made with different edible oils and WPC or PWP.

T1: full fat butter oil with WPC, T2: full fat rice bran oil with WPC, T3: full fat palm Olein with WPC, T4: full fat butter oil with PWP, T5: full fat rice bran oil with PWP, T6: T3: full fat palm Olein with PWP.

Different superscripts at the same column are significantly different (P<0.05).

WPC: Whey proteins concentrate **PWP: polymerized Whey protein**

a. Color attributed of fresh spreadable processed cheese analogues with different edible oils and WPC or PWP

Table (7) showed that the addition of RBO significantly improved the color of T2 and T5 as compared to treatments with BO (T1 and T4). This may be due to that the different type of proteins. On the other hand T5 contained PWP was lighter than T2. The higher lightness values were found in full fat bran rice oil with polymerized whey protein when compared to other samples due to the high light scattering ability of fat globules of bran rice oil. It concluded that final color of processed cheese depend not only oil content, but also the oil dispersion in protein matrix during processed cheese process.The type of fat used significantly (P < 0.05) affected all the colour parameters evaluated the spreadable cheese analogues manufactured with partially hydrogenated soybean fat and soybean oil presented greater whiteness indexes and lower yellowness indexes than the product manufactured with butter oil. The variation in colour between the products under test was essentially related to the type of fat used. Milk fat traditionally presents a yellowish colour because of the presence of liposoluble pigments, especially carotenoids, obtained from the animal's diet. On the other hand, during the refining process, which remove the majority of the liposoluble pigments present in the crude oil. Fat particle size may also have contributed to the colour presented by the products, as the smaller the fat globule diameter the greater the lighter dispersion, resulting in a whitish colour this results were agreement with Cunha et al. (2013). Also, they showed that the total color difference values increased with the decrease in the concentration of camel cheese based. The results were expressed as lightness (L*), redness (a*) and yellowness (b*) on colour parameter oxidative processes any cheese, imitation cheese products leads to the degradation in lipid and proteins which in contribution to the deterioration in color.

Treatment	Color parameters		
	L*	a*	b*
T_1	88.46±0.302^{c}	0.76±0.040^{d}	13.15±0.392^{c}
T_2	90.37±0.222^{b}	0.52±0.030^{e}	12.64±0.360^{c}
T_3	84.71±0.457^{d}	1.41±0.040^{b}	12.78±0.279^{c}
T_4	89.68±0.374^{b}	0.90±0.036^{c}	14.87±0.161^{a}
T_5	91.54±0.277^{a}	0.61±0.321^{e}	14.13±0.236^{b}
T_6	85.29±0.809^{d}	2.01±0.112^{a}	13.99±0.497^{b}
LSD	**0.8028**	**0.0995**	**0.6034**

Table 7: Changes in color attributed of spreadable processed cheese analogues with different edible oils and WPC or PWP.

T1: full fat butter oil with WPC, T2: full fat rice bran oil with WPC, T3: full fat palm Olein with WPC, T4: full fat butter oil with PWP, T5: full fat rice bran oil with PWP, T6: T3: full fat palm Olein with PWP.

Different superscripts at the same column are significantly different (P<0.05).

WPC: Whey proteins concentrate **PWP: polymerized Whey protein**

L* indicates lightness

a* is the red/green coordinate

b* is the yellow/blue coordinate.

a. Sensory evaluation of fresh spreadable processed cheese analogues with different edible oils and WPC or PWP

Data in Table (8) summarized the sensory scores of the six treatments of spreadable processed cheese analogues. Treatment 1 and 4 recorded the highest total score (95.03 and 95.80, respectively) while T3 recorded the lowest one (86.07). Data obtained in the same Table show that treatment T3 and T6 (contained Palm Olein) exhibited significantly the lower quality attributes compared to the other treatments which may be due to that the Palm Olein negatively affect sensory characteristics of cheese especially color and body and texture. Cunha et al. (2013). Showed that the product manufactured with butter oil was much better evaluated by the consumers, although, the spreadable cheese analogue manufactured with partially hydrogenated soybean fat also showed good sensory acceptance. There for it has good potential to substitute butter oil. On the other hand, the analogues manufactured with soybean oil was less accepted than that of manufactured partially hydrogenated soybean fat which must associate with reduced oxidative stability of soybean oil.

Chatziantoniouet al (2015). Opserved that spreadable processed cheese whey were noted as highly acceptable in terms of aroma-flavour- texture and overall acceptance.

Alnemret al (2015). They indicated that sensory evaluation of low fat spreadable processed cheese analogue The synergized replaced and substituted milk protein concentrate with 2% synergized filler “Gervizol” (soy proteins, soy fibers, maltodextrine and modified starch) had significantly higher flavor, spreadability and color . Wang et al (2017). Indicated that sensory evaluation of set-type fermented goat milk with Kefir Mild 01 with PWP and pectin had higher scores of both flavor and taste than control without PWP. Polymerized whey protein may be a novel protein-base thickening agent for formulation of fermented goat milk. Sakanderet al. (2014) revealed that polymerized whey protein as a stabilizer may be useful to improve the organoleptic properties of Camel milk stirred yoghurt.

Treatment	Appearance (10)	Color (10)	Body & Texture (40)	Flavor (40)	Total score (100)
T_1	9.43±0.208^{a}	9.30±0.200^{a}	37.80±0.608^{ab}	38.50±0.917^{a}	95.03±1.250^{a}
T_2	9.27±0.252^{a}	8.77±0.153^{ab}	37.20±1.442^{abc}	38.00±0.917^{ab}	93.23±1.914^{a}
T_3	8.33±0.252^{c}	7.60±0.656^{c}	35.33±1.850^{c}	35.80±1.778^{b}	86.07±3.729^{b}
T_4	9.20±0.400^{ab}	9.37±0.252^{a}	38.83±0.764^{a}	38.93±0.115^{a}	95.80±0.346^{a}
T_5	9.30±0.200^{a}	8.50±0.173^{b}	38.40±0.529^{a}	38.10±0.755^{a}	94.30±0.364^{a}
T_6	8.60±0.300^{bc}	8.40±0.529^{b}	35.43±2.113^{bc}	35.77±2.108^{b}	88.20±4.051^{b}
LSD	**0.4929**	**0.6766**	**2.4319**	**2.2819**	**4.3467**

Table 8: The sensory evaluation of spreadable processed cheese analogues with edible oils and WPC or PWP.

T1: full fat butter oil with WPC, T2: full fat rice bran oil with WPC, T3: full fat palm Olein with WPC, T4: full fat butter oil with PWP, T5: full fat rice bran oil with PWP, T6: T3: full fat palm Olein with PWP.

Different superscripts at the same column are significantly different (P<0.05).

WPC: Whey proteins concentrate PWP: Polymerized Whey protein

Souzaet al. (2017) Palm oleincontains 40-42.5% palmeticacid. The observation of a high correlation between calcium and palmitic acid excretion in infants fed formula containing palm olein resulting in low calcium absorption. The use of powdered formula that is free of palm olein and palm kernel oil is associated with improved intestinal absorption of the major fatty acids and total fat, as well as calcium retention. Palm oil might be free of trans fats, but it’s high in saturated fats, which pose a significant risk to cardiovascular health. but less healthy than liquid oils like olive According the European Food Safety Authority (EFSA) raised concerns that high levels of 3-MCPD – a substance found in refined palm oil – could pose risk to kidneys, and the male reproductive system. While 3-MCPD is suspected to be carcinogenic, EFSA they revised their guidelines earlier this year, increasing the safe consumption levels of the compound (Bowman, 2018 and Picncu, 2019). They found that replacing this fat with vegetable oils rich in polyunsaturated fats may lower the risk of coronary heart disease by up to 30 percent and reduce cholesterol levels. Also, They reported that still limitations in study showed that palm olein with high ratio of saturated fatty acids in dietary oil may not affect the lipid profiles, the insulin resistance, and the function of liver and kidney.

Conclusion

This study showed that replacing milk fat with vegetable oils (RBO and PO) did not affect the appearance, color and tenderness, but significantly ($p \leq 0.05$) affected the flavor of the cheese analogues. The addition of rice bran oil (RBO) had significant effects on the composition and quality of the spreadable processed cheese analogues. The addition of RBO increased and improved the flavor, body, texture, color and appearance characteristics.

Author contributions statement

Mahassensleem: Conceptualization, The work administration, and writing—original draft.

Sally sakr: Methodology, investigation, formal analysis, statistical, data curation

Hamdy A. Shaaban: writing—review and editing and Final review and check results, Plagiarism and publishing.

All authors have read and agreed the contents of the manuscript. Also, we confirm that, replicates for the study experiments in comparison to the experiments performed in our lab in Egypt.

Data availability Research data are not shared.

Statements and Declarations

Competing interest The authors declare no conflict of interest of any kind.

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