Characterisation of soft white cheese fortified with flaxseed oil to enhance its quality, lipid profile and health benefits

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This study aimed to investigate the influence of flaxseed oil addition on the chemical composition and fatty acid profile of soft white cheese. The physicochemical characteristics (moisture, ash, salt, fat, protein, carbohydrate, and energy), pH, TBARS, fatty acid profile and sensory properties of soft white cheese samples were studied during 7 weeks of storage. Results showed that cheese moisture ranged from 58.16-65.37%, ash 1.54%-2.7%, protein 10.41%-12.97%, and fat 16.46%-20.06%. Fortification of White soft cheese with flaxseed oil have led to changes in the values of health lipid indices associated with a significant decrease in the values of Atherogenic index, Thrombogenic index, Lipid Preventive Score and n6/n3 ratio, in addition to a significant increase in Health Promoting Index, Desirable fatty acids, and polyunsaturated/saturated fatty acids ratio which were within the range of the optimal values for healthy nutrition. There was a clear difference in the chemical composition and fatty acid profile between the control and the fortified cheeses. The conclusion was that omega-3, which is an excellent nutrient, can be easily added to cheese with desirable changes.

Keywords: white brined cheese, Flaxseed oil, Fatty acid profile, health indices.

INTRODUCTION

In the East Mediterranean and neighbouring countries, such as Serbia, white brined cheeses are the most popular type of cheese. They are typically consumed locally, but the demand for this type of cheese is increasing in markets around the world [1].

Soft white cheese, which is described as the fresh or ripened product formed after coagulation and whey separation of milk, cream or partly skimmed milk, buttermilk, or a blend of these products, is the most common cheese type made in Jordan [2]. It can also be made from ovine, buffalo, bovine and/or caprine milk or from mixtures of these milks [3]. The production procedure can be characterised by the rennet coagulating the milk for 40-60 minutes after heating to around 35°C and pressing in cheese cloth. The cheese is frequently consumed immediately after manufacturing or used to make Arabian confectioneries like kunafeh [4]. Cheese has a long history in human diet as a source of critical nutrients, since it is a rich source of protein and nutritional elements (such as calcium and phosphorus) and is also necessary for the development of healthy bones and teeth, as well as providing essential fatty acids to the brain [5, 6].

As a result, individuals are increasingly aware of the importance of including such items in their diet to preserve and improve their quality of life [7]. In recent years, consumers have become more aware of the significance of maintaining an appropriate nutrition. In cheese manufacture, vegetable fats and oils replaced saturated milk fat, resulting in food formulations with elements that help minimise health hazards. The nutritional profile of cheese is improved by using high-quality vegetable fat as a substitute for milk fat,

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resulting in a reduction in cholesterol and a shift in saturated and unsaturated fatty acid content [8].
Food engineers and nutritionists are working hard to create nutritious and healthful foods. Incorporating nuts, fruits, vegetables, oils, herbs, and spices into the formulations of processed foods is one of the approaches [9]. Flaxseed oil (FO) is naturally low in saturated fat, high in monounsaturated fat, and notably high in alpha-linolenic acid (ALA), an omega-3 fatty acid; it contains less linoleic acid (LA), an omega-6 fatty acid. Flaxseed oil has a 1:3 omega-6/omega-3 fatty acid ratio due to its high ALA content [10].
Producers developed low-fat food items in response to the consumer's desire to reduce fat intake; making reduced-fat goods with the same qualities and functions as full-fat products, on the other hand, is a difficult task. Low-fat and reduced-fat cheeses are commonly described as soft, hard, rubbery, and discoloured. Fewer fat globules are integrated into the protein matrix in low-fat cheeses, and these globules are typically smaller than in full-fat cheese. As a result, using fat substitutes to improve the quality of low-fat cheeses is a viable option [11].
The link between nutrition and health is becoming more widely recognised among consumers. Many people believe milk fat to be "bad", and scientists are being pressed to explain the role of nutrition in chronic diseases. As a result, numerous markers - lipid indices - have been developed to assess the preventative characteristics of meals [12].
Due to the potential negative health effects of saturated fatty acids and cholesterol in high-fat cheese, the primary goals of this study were to examine the physicochemical, fatty acid composition and sensory properties of soft white cheese fortified with flaxseed oil, which is rich in unsaturated fatty acids, particularly omega-3, to benefit from the advantageous health effects of these acids in lowering the incidence of heart disease, as well as health-related lipid indices, like the Atherogenic and Thrombogenic indices (AI and TI, respectively).

MATERIALS AND METHODS

PREPARATION OF WHITE SOFT CHEESE FORTIFIED WITH FLAXSEED OIL

Cheese production was carried out at the dairy pilot plant, Mazraa dairy factory located in Amman, Jordan according to Gurdian et al. [13] with some modification. Ten kilograms of raw milk were pasteurised at 72°C for 15 seconds. Approximately 1 g Flaxseed Oil (FO) was added per 1 litre of milk at the homogenisation processes. Rennet was dissolved in a small amount of distilled water and added to milk and afterwards incubated at room temperature for 30 min until the milk was coagulated. The curd was cut using a knife and pressed in a cheese mould containing cheese cloth. Afterwards, it was recreated and shaped well and soaked overnight in a cold brine solution consisting of 10% salt. Three soft white cheese formulations were produced: Control (SCN) was manufactured from fresh whole cow milk, soft white cheese fortified with flaxseed oil (SCO) (whole cow's milk + 1% flaxseed oil), and reduced fat soft white cheese fortified with flaxseed oil (RSCO) (skim milk + 1% flaxseed oil). Cheese samples were packed in transparent plastic containers and kept in the refrigerator at 4°C until the time of analysis.

ANALYTICAL METHODS

Cheese samples were analysed for moisture, fat, protein, salt, ash, and pH according to AOAC [14]. Carbohydrate amounts were determined according to Cebeci et al. [15] by determining the moisture, ash, protein and fat amounts of cheese and subtracting them from 100

$$\%CHO = 100 - (\%Moisture + \%Protein + \%Fat + \%Ash)$$

Total energy content of samples was calculated using a conversion factor for each energy yielding substrate of each food sample according to Nunoo [16].

LIPID OXIDATIVE STABILITY OF STORED MANUFACTURED WHITE CHEESES (TBARS)

White soft cheeses were analysed for lipid oxidation by determining thiobarbituric acid reactive substances (TBARS) according to the method described by Faustman et al. [17] and Johns [18]. The absorbance of the resulting solution was measured at 532 nm using a UV-vis spectrophotometer (spectro 2000 spectrophotometer, LaboMed.Inc). The thiobarbituric numbers (TBN) in mg of malondialdehyde/kg sample were calculated by multiplying the measured absorbance by a factor of 7.8.

DETRMINATION OF FATTY ACIDS PROFILES

Fatty acid methyl esters of the fat of the soft white cheese samples were prepared according to the method described by Chritopherson and Glass [19]. The prepared methyl esters were analysed using capillary GLC column (Restek, Rtx-225, USA, crossbond 100%-cyanopropylmethylpolysiloxane, 100 m, 0.25 µm df) immediately after esterification by injection 1 µl of the hexane layer through the injection port of the GLC (model GC-2010, shimadzu Inc., Kyoto, Japan). The fatty acids methyl esters (FAMEs) were injected after adjusting the GLC condition; column oven temperature was 70°C, increased to 165°C for 10 min., kept at 185°C for 1 min, then increased to 220°C for 15 min. Injector temperature was 240°C flame ionisation detector temperature was 250°C, flow rate 1 ml/min He, and split ratio used was 80. The fatty acids peaks were identified by comparing with the retention time of the reference standards. The quantification of the methyl ester fatty acids was then done by: Area of the fatty acid% / total area of fatty acids [20]. The areas of the peaks were corrected by the theoretical correction factors (TCF).

The TCF for the fatty acids less than 16 carbon atoms: (C4:0), (C6:0), (C8:0), (C10:0), (C12:0), (C14:0), (C14:1), (C15:0), (C15:1), (C16:0) were 1.540, 1.308, 1.193, 1.123, 1.077, 1.067, 1.058, 1.054, 1.045, 1.042 respectively.

HEALTH NUTRITIONAL INDICES

The Atherogenic index (AI) and Thrombogenic index (TI) were calculated according to Ulbricht and Southgate [21].

$$AI = 12{:}0+4\times14{:}0+16{:}0/[\Sigma MUFAs+PUFAn6+PUFAn3]$$

$$TI = (14{:}0+16{:}0+18{:}0)/[0.5\times\Sigma MUFAs+0.5\times PUFAn6+3\times PUFAn-3+PUFAn3/PUFAn6]$$

Desired fatty acid (DFA), Lipid preventive score (LPS) were determined according to Lima et al. [22]

$$DFA = \sum MUFA + \sum PUFA + C18{:}0$$

$$LPS = FAT+2\times SFA-MUFA-0.5PUFA$$

Health-promoting index (HPI) was calculated according to Chen et al. [23] to assess the nutritional value of dietary fat, which focuses on the effect of FA composition on CVD. The formula is:

$$HPI = \Sigma UFA/[C12{:}0 + (4 \times C14{:}0) + C16{:}0]$$

DETERMINATION OF CHOLESTEROL CONTENT

Cholesterol was extracted by enzymatic hydrolysis and oxidation according to Boehringer [24]. In which Cholesterol is oxidised by Cholesterol oxidase to cholestenone. In the presence of catalase, the hydrogen peroxide produced by this reaction oxidises methanol to formaldehyde. The latter, in turn, reacts with acetyl acetone, forming a yellow lutidine dye with ammonium ions. The concentration of the lutidine dye formed is stoichiometric with the amount of CHOL and is measured at 405 nm.

Calculation:

$$c=0.711\times\Delta A(g/l\text{sample solution})$$

$$\text{Content cholesterol} = \frac{(\text{c cholesterol g/l solution})}{(\text{weight of sample in g/l sample solution})} \times 100(g/100g)$$

ΔA (subtract absorbance of the blank from the absorbance of the sample)

SENSORY EVALUATION

Sensory testing was conducted in the sensory evaluation lab at the University of Jordan. Sensory evaluation of cheese samples was performed by a group of twenty specially trained panellists belonging to the staff and students of the Faculty of Agriculture at the University of Jordan who were recruited to evaluate samples using a 9-point hedonic scale (where 1 = dislike extremely, and 9 = like extremely). Samples were given random numbers so the panellists gave their opinion without knowing the sample type. Parameters of appearance, colour, aroma, flavour, softness, texture, and overall acceptability were assessed through the test. Data collected from the panellists were subjected to a statistical analysis [4].

STATISTICAL ANALYSIS

All measurements were performed in triplicate and mean values were reported. Analysis of variance (ANOVA) using JMP (release 10, SAS institute, Cary, NC) was carried out to determine any significant differences among the treatment parameters associated with the developed cheese properties. Least significant difference (LSD) at 5% level of probability was determined to separate differences in the properties among treatments.

RESULTS AND DISCUSSION

PROXIMATE ANALYSIS

Table I shows the proximate analysis of the control and FO-fortified soft cheeses. Moisture contents of cheeses ranged from 58.16% for soft white cheese fortified with FO (SCO), to 65.37% for reduced soft white cheese sample fortified with FO (RSCO). Moisture level of RSCO was found to be significantly higher ($p < 0.05$) than both the control (SCN) and SCO; which were insignificantly different. This indicates that the addition of FO has reduced the moisture content of soft white cheese. Similar results were reported by Aguirre and Canovas [25], which could be linked to the cheese's water-holding capacity (WHC) as a possible explanation for the decrease in moisture.

Haddad and Yamani [4] reported that the moisture content of soft cheese in major governorates of Jordan ranged between 39.5 and 74.5% with an average of 56.5%. Al-Manhal [26] demonstrated that the

Table I - Proximate analysis* of soft white cheese samples fortified with flaxseed oil.

Samples	Moisture (g/100g)	Ash (g/100g)	Protein (g/100g)	Fat (g/100g)	NaCl (g/100g)	CHO (g/100g)	Energy (Kcal)
SCN	$58.52^{b} \pm 0.46$	$1.79^{a} \pm 0.57$	$12.04^{b} \pm 0.03$	$20.06^{a} \pm 0.08$	$1.30^{a} \pm 0.1$	$7.57^{b} \pm 0.28$	$259.00^{a} \pm 0.53$
SCO	$58.16^{b} \pm 0.55$	$2.17^{a} \pm 0.002$	$12.97^{a} \pm 0.08$	$17.96^{b} \pm 0.08$	$1.34^{a} \pm 0.09$	$8.72^{a} \pm 0.54$	$248.43^{b} \pm 2.34$
RSCO	$65.37^{a} \pm 0.46$	$1.54^{a} \pm 0.15$	$10.41^{c} \pm 0.05$	$16.46^{c} \pm 0.08$	$1.05^{b} \pm 0.04$	$6.21^{c} \pm 0.74$	$214.64^{c} \pm 2.06$

*Values are means of triplicate determinations ±SD

^{a,b,c} lower case letters within each column indicate statistically significant differences ($P < 0.05$).

SCN: Regular soft white cheese (i.e., control), SCO: Soft white cheese fortified with flaxseed oil, RSCO: Reduced soft white cheese fortified with flaxseed oil

moisture content of soft cheese ranged between 55.33-69.85%. Our results agreed with the results indicated above.

The ash content ranged from 1.54% for RSCO, to 2.17% for SCO. According to the performed statistical analysis, there were no significant differences ($p > 0.05$) in ash contents among different samples. The low ash content of pasteurized milk cheese could be explained by the diffusion of salts from the curd into the pickling solution because of high moisture content in cheese. The results obtained were lower than those of Haddad and Yamani [4] and Mahrous [27] who found that the ash percentage of soft cheese in major governorates of Jordan ranged between 3.3 and 17.3 with an average of 9.5%, and in white cheese manufacturing processes using FO and skim milk, it ranged from 3.3% to 3.60%, respectively.

Significant differences in fat content ($p < 0.05$) were found between cheese samples, where values ranged from 16.46% for RSCO, to 20.06% of total cheese weight for SCN. The fat content decreased in reduced white soft cheese fortified with FO, whereas the moisture increased. These results agreed with those of Mahrous [27], Akan and Kinik [28] and Manuelian et al. [29].

Regarding protein content, significant differences in ($p < 0.05$) were detected between cheese samples, where values varied from 10.41% for RSCO, to 12.04% for SCN and 12.97% for SCO. In this study, protein content was like that reported by Salwa and Galal [30] who found a value of 13.8%, and lower than the findings of Haddad and Yamani [4] and Manuelian et al. [29] who reported a protein content of 16.4% and 15.66 to 19.73%, respectively.

As shown in Table I, salt (i.e., NaCl) contents ranged from 1.05% in RSCO, to 1.34% in SCO. Values of the control and SCO were statistically similar, whereas RSCO showed a significantly ($p < 0.05$) lower value. Salt helps in controlling microbial growth and activity, slowing down various enzyme activities, reducing moisture content, and preventing physical changes in proteins; all of which can affect the cheese texture and flavour [31]. The results agreed with those reported by Gomes et al. [32].

As seen in Table I, there were significant differences regarding carbohydrate (CHO) content among the control and the fortified treatments. Values varied between 6.21, 7.57 and 8.72 for RSCO, SCN and SCO, respectively. The lowest CHO value was in RSCO, whereas the highest was in SCO cheese.

Mean caloric values of the cheese samples are also presented in Table I. The lowest calorie content (214.64 kcal/100g) was, as expected, determined in the RSCO, whereas the highest value detected (259.00 kcal/100g) was in the regular soft white cheese. It is a well-known fact that fat content is an important factor in calculating the energy value of foods [33]. Consequently, values were consistent with each sample's fat level; since the lowest fat content was detected in RSCO, and the highest was found in the control.

OXIDATIVE STABILITY OF STORED MANUFACTURED WHITE CHEESES (TBARS)

Figure 1 demonstrates the weekly-measured TBARS values of the FO-fortified soft white cheeses during a storage period of 2 months. Values were significantly ($p < 0.05$) greater in the control as compared with fortified white soft cheeses; at which it (i.e., SCN) showed a significant increase from week 0 to week 4,

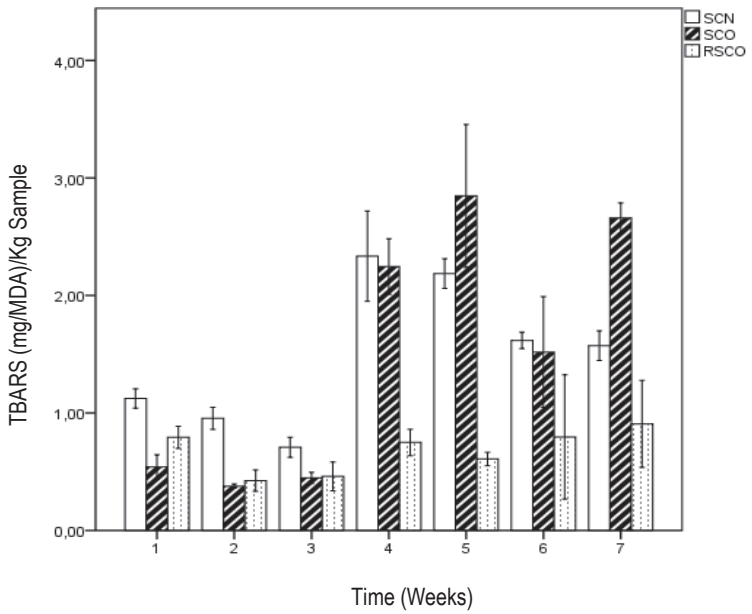

Figure 1 - TBARS of soft white cheeses incorporated with flaxseed oil during a storage period of 7 weeks at 4°C.
SCN: Regular soft white cheese (i.e., control), SCO: Soft white cheese fortified with flaxseed oil, RSCO: Reduced soft white cheese fortified with flaxseed oil. TBARS = Thiobarbituric-acid-reactive-substances, MDA = Malondialdehyde.

followed by a drop from week 5 to week 7.
SCO showed a significant increase ($p < 0.05$) in TBARS values from week 0 to week 7. It had significantly higher TBARS than the other treatments. This indicates that less secondary oxidative products were found in the control and RSCO when FO was added. RSCO had the lowest TBARS values during the entire storage period, which can be linked to the lower amount of fat in the cheese. Interestingly, the development of rancid off-flavour in FO-based skimmed milk cheese products was quite stable against oxidation, intense lighting, and is predicted to be very low during storage at 4°C [27]. Chen et al. [22] and Simbalista et al. [34] reported that ALA is a component in oil which is susceptible to auto-oxidation and polymerisation when exposing to air, light or high temperatures.
These results agreed with Abd el-aziz et al. [35] who found that TBA values of Egyptian white brined cheese increased during storage until 2 months. According to Sallam [36], the maximum level of TBARS is 5 mg malondialdehyde/kg sample for good quality food. Meanwhile, TBARS values obtained in the present study for SCN, SCO, and RSCO were 1.57, 2.65, and 0.9 mg malondialdehye/kg sample, respectively.

PH

Figure 2 shows the weekly-measured pH values of FO-incorporated soft white cheeses during storage for 2 months at 4°C. There was a significant difference ($p < 0.05$) between all samples. The lowest pH detected was in RSCO, whereas the greatest was in SCO. During the ripening period, pH values among cheese samples fluctuated between 6.7-6.47 for the control, 6.92-6.36 for SCO and 6.49-6.08 for RSCO. The pH values generally decreased throughout maturation for all samples, which is a sign of over-fermentation [37]. This decreasing trend in pH of white cheeses was observed till up to 2 months of storage. Similar values of pH were reported by Gurdian et al. [13] and Haddad and Yamani [4].
According to Ismail et al. [38], cheese containing vegetable oils showed slightly higher pH values than the control cheese. These results reflect the low amount of lactose content in the control cheese. In addition, increasing the level of milk fat substitution leads to a slight decrease in pH value. Additionally, Effat et al. [39] reported that the short chain fatty acids, which are produced in varied amounts as a metabolic end product of probiotic bacteria, may be responsible for the reduction in pH values.

FATTY ACID PROFILE

Table II presents the fatty acid profile (i.e., saturated, monounsaturated, polyunsaturated and trans fatty acids) of FO-fortified soft white cheeses, as well as FO. Additionally, the sum of lipid (SFA, MUFA, PUFA, Trans FA, n-6 and n-3) composition, and nutritional quality indices (Atherogenic index (AI); Thrombogenic index (TI); desirable fatty acids (DFA); lipid preventive score (LPS); health-promoting index (HPI); and n6/n3 ratio) of fortified soft white cheeses and FO are listed in Table III.
Analysis of fatty acid profile in the control and fortified soft white cheeses identified a total of 23 fatty acids where the control had the greatest SFA percentage, and both SCO and RSCO cheeses had the highest PUFA, ALA, and n-3 and n-6 percentages (Table III).
A significant difference was detected between the control and other experimental treatments; noting that there was a significant decrease in the concentration

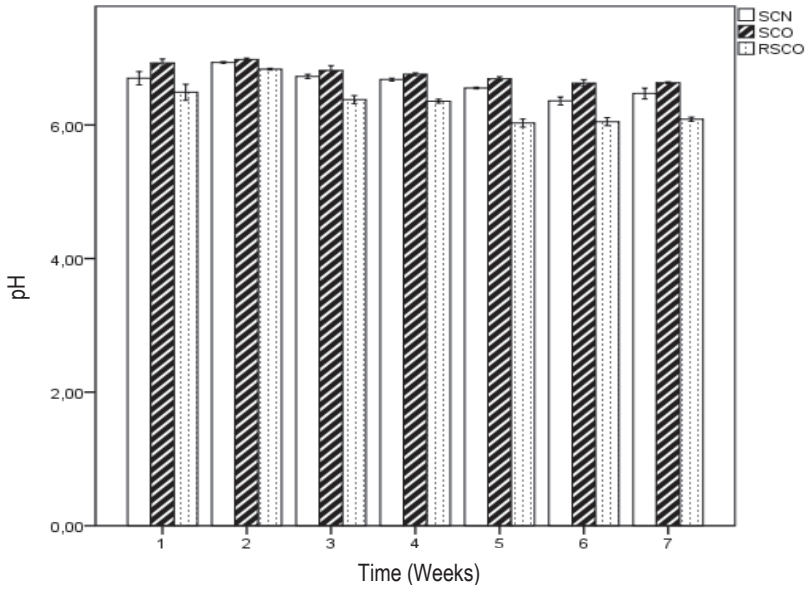

Figure 2 -The pH of soft white cheeses fortified with flaxseed oil during a storage period of 7 weeks at 4°C.
SCN: Regular soft white cheese (i.e., control), SCO: Soft white cheese fortified with flaxseed oil, RSCO: Reduced soft white cheese fortified with flaxseed oil.

Table II - Saturated, monounsaturated, polyunsaturated and trans fatty acids (g/100g total FA) of fortified soft white cheeses and flaxseed oil.

Item	Samples			
	SCN	SCO	RSCO	FO
Saturated fatty acids				
C4:0 Butyric acid	$1.80^{a} \pm 0.04$	$1.36^{c} \pm 0.03$	$1.52^{b} \pm 0.03$	ND^{d}
C6:0 Caproic acid	$0.60^{a} \pm 0.01$	$0.28^{c} \pm 0.007$	$0.44^{b} \pm 0.01$	ND^{d}
C8:0 Caprylic acid	$1.17^{a} \pm 0.02$	$0.79^{c} \pm 0.01$	$0.97^{b} \pm 0.02$	ND^{d}
C10:0 Capric acid	$3.06^{a} \pm 0.07$	$2.09^{c} \pm 0.05$	$2.42^{b} \pm 0.05$	ND^{d}
C12:0 Lauric acid	$3.93^{a} \pm 0.09$	$2.74^{c} \pm 0.06$	$3.02^{b} \pm 0.07$	$0.03^{d} \pm 0.0008$
C14:0 Myristic acid	$12.94^{a} \pm 0.31$	$9.11^{c} \pm 0.22$	$9.61^{b} \pm 0.23$	$5.30^{d} \pm 0.12$
C15:0 Pentadecylic acid	$1.55^{a} \pm 0.03$	$1.10^{b} \pm 0.02$	$0.94^{c} \pm 0.02$	ND^{d}
C16:0 Palmitic acid	$39.15^{a} \pm 0.95$	$29.40^{b} \pm 0.71$	$29.85^{b} \pm 0.72$	ND^{d}
C17:0 Heptadecanoic acid	$0.76^{a} \pm 0.01$	$0.53^{b} \pm 0.01$	$0.55^{b} \pm 0.01$	ND^{d}
C18:0 Stearic acid	$9.18^{a} \pm 0.22$	$7.98^{c} \pm 0.19$	$8.64^{b} \pm 0.21$	$4.19^{d} \pm 0.1$
C20:0 Arachidic acid	$0.34^{a} \pm 0.008$	$0.26^{b} \pm 0.006$	$0.26^{b} \pm 0.06$	$0.15^{c} \pm 0.003$
C22:0 Behenic acid	$0.15^{a} \pm 0.003$	$0.1^{b} \pm 0.002$	$0.1^{c} \pm 0.002$	$0.02^{d} \pm 0.0005$
C24:0 Lignoceric acid	$0.2^{a} \pm 0.004$	$0.12^{c} \pm 0.002$	$0.25^{d} \pm 0.0006$	$0.19^{b} \pm 0.004$
Monounsaturated fatty acids				
C14:1 Myristoleic acid	$0.007^{d} \pm 0.0001$	$0.06^{a} \pm 0.001$	$0.012^{c} \pm 0.0003$	$0.05^{b} \pm 0.001$
C15:1 cis-10-Pentadecenoic acid	$0.31^{a} \pm 0.007$	$0.22^{b} \pm 0.005$	$0.22^{b} \pm 0.005$	$0.03^{c} \pm 0.0009$
C16:1 Palmitoleic acid	$2.39^{a} \pm 0.58$	$1.71^{b} \pm 0.04$	$0.15^{c} \pm 0.003$	ND^{d}
C17:1 cis-Heptadecenoic acid	$0.23^{a} \pm 0.005$	$0.17^{b} \pm 0.004$	$0.17^{b} \pm 0.004$	ND^{d}
C18:1 (n-9)-Oleic acid	$21.69^{ab} \pm 0.52$	$21.18^{bc} \pm 0.51$	$22.21^{a} \pm 0.54$	$20.34^{c} \pm 0.49$
Polyunsaturated and Trans fatty acids				
C18:2 (n-6)-Linoleic acid	$3.57^{c} \pm 0.08$	$6.6^{b} \pm 0.16$	$6.81^{b} \pm 0.16$	$15.51^{a} \pm 0.37$
C18:3 α-Linolenic acid	$0.51^{d} \pm 0.01$	$17.67^{b} \pm 0.43$	$16.17^{c} \pm 0.39$	$55.05^{a} \pm 0.34$
C18:1 trans trans-9-Elaidic acid	$1.52^{b} \pm 0.03$	$0.71^{c} \pm 0.01$	$0.49^{d} \pm 0.01$	$1.59^{a} \pm 0.03$
C18:2 trans-Linolelaidic acid	$1.11^{a} \pm 0.02$	$0.92^{b} \pm 0.02$	$0.74^{c} \pm 0.01$	$0.05^{d} \pm 0.001$
C18:3 trans	$0.28^{a} \pm 0.006$	$0.22^{b} \pm 0.005$	$0.21^{b} \pm 0.005$	$0.28^{a} \pm 0.006$

*Values are means of triplicate determinations ±SD

^{a,b,c,d} Different letters within the same row differ significantly at $p < 0.05$.

SCN: Regular soft white cheese, SCO: Soft white cheese fortified with flaxseed oil, RSCO: Reduced soft white cheese fortified with flaxseed oil, FO: Flaxseed oil.

of short-chain fatty acids and saturated fatty acids in cheeses incorporated with FO (i.e., SCO and RSCO), and an increase in C18:2 and C18:3 compared to the control sample. Similar findings were reported by Veena et al. [40]. This has a positive impact on reducing cholesterol and the risk of heart disease [41].

In the control sample, palmitic acid (C16:0) was the most abundant fatty acid, followed by myristic (C14:0), and stearic (C18:0) acids. In cheeses containing FO, oleic acid (C18:1) was the most abundant fatty acid, followed by palmitic (C16:0), linolineic (C18:3), myristic (C14:0) and stearic (C18:0) acids. The fatty acids C18:1, C18:2 and C18:3 are some of the most vital fatty acids that are necessary to maintain human health [9]. Oleic, linoleic, and stearic acids have a higher perception threshold and are thought to play a less important role in cheese flavour [42].

A significant ($P < 0.05$) increase in mono-poly unsaturated fatty acid (MUFA- PUFA) in cheese supplemented with FO compared to the control cheese sample. These results are attributable to the addition of flaxseed, which is high in linolenic, oleic, linoleic, and conjugated linoleic acid (CLA), and low in palmitic acid.

Saturated fatty acids ranged from 74.89% in control, 55.92% in SCO and 58.39% in RSCO. Our findings, regarding SFA contents, were like those reported by Donmez et al. [43]. Specific SFA are involved in cell regulation and gene expression, n-3 FA produce anti-inflammatory eicosanoids [29].

Goyal et al. [44] also reported that dahi (Indian yoghurt) fortified with microencapsulated FO powder at 2% level showed an increased ALA content (10.62% of total fatty acids) compared to control dahi (1.92% ALA).

As demonstrated in Table III, trans fatty acids varied from 2.91% in SCN, to 1.86% in SCO and 1.46% in RSCO, while were 1.93% in FO. Our samples had considerably less trans fatty acids in total fatty acids. Trans fatty acids are found in ruminant fats (dairy products, beef, lamb) because of bacterial action in the rumen, as well as in shortening and spreads as a result of industrial hydrogenation of oils [45].

The control showed ALA content of 0.51%, LA content of 3.57% and oleic acid of 21.69%. The FO incorporated in cheese had oleic acid level of 20.34%, LA around 15.51%, and ALA around 55.05%. Thus, it is evident that supplementation of FO has significantly

Table III - The sum of lipid (SFA, MUFA, PUFA, Trans FA and n-6, n-3) composition, and nutritional quality indices; Atherogenic index (AI), Thrombogenic index (TI), desirable fatty acids (DFA), lipid preventive score (LPS), health-promoting index (HPI),PUFA/SAF, and n6/n3 ratio of fortified soft white cheeses and flaxseed oil.

Sample	ΣSFA	ΣMUFA	ΣPUFA	ΣTrans	n6	n3	AI	TI	DFA	LPS	HPI	n6/n3	PUFA/SFA
SCN	$74.89^{a} \pm 1.83$	$25.15^{a} \pm 0.45$	$4.08^{c} \pm 0.09$	$2.91^{a} \pm 0.07$	$3.57^{c} \pm 0.08$	$0.51^{d} \pm 0.01$	$3.24^{a} \pm 0.09$	$3.81^{a} \pm 0.09$	$38.42^{c} \pm 0.46$	$142.66^{a} \pm 3.70$	$0.26^{d} \pm 0.009$	$6.91^{a} \pm 0$	$0,05^{d} \pm 0.000004$
SCO	$55.92^{b} \pm 1.36$	$23.36^{b} \pm 0.56$	$24.27^{b} \pm 0.59$	$1.86^{b} \pm 0.04$	$6.60^{b} \pm 0.16$	$17.67^{b} \pm 0.43$	$1.43^{b} \pm 0$	$0.65^{c} \pm 0.0005$	$55.62^{b} \pm 1.35$	$94.31^{b} \pm 1.78$	$0.34^{b} \pm 0$	$0.37^{c} \pm 0$	$0,43^{b} \pm 0$
RSCO	$58.39^{b} \pm 1.42$	$22.79^{b} \pm 0.55$	$22.99^{b} \pm 0.56$	$1.46^{c} \pm 0.03$	$6.81^{b} \pm 0.16$	$16.17^{c} \pm 0.39$	$1.55^{b} \pm 0$	$0.73^{b} \pm 0.0005$	$54.42^{b} \pm 1.32$	$98.97^{b} \pm 1.93$	$0.31^{c} \pm 0$	$0.42^{b} \pm 0$	$0,39^{c} \pm 0$
FO	$9.79^{c} \pm 0.41$	$20.43^{c} \pm 0.49$	$70.56^{a} \pm 1.72$	$1.93^{b} \pm 0.04$	$15.51^{a} \pm 0.37$	$55.05^{a} \pm 1.34$	$0.23^{c} \pm 0$	$0.05^{d} \pm 0.00002$	$95.19^{a} \pm 2.32$	$63.86^{c} \pm 0.58$	$0.96^{a} \pm 0.13$	$0.28^{d} \pm 0$	$7,20^{a} \pm 0.14$

Values are means of triplicate determinations ±SD.
The results are shown as a percentage of total FA
a,b,c,d Superscripts within the same column differ indicate significant differences ($p<0.05$).
SFA: saturated fatty acid, MUFA: monounsaturated fatty acid, PUFA: polyunsaturated fatty acid, n-6: omega 6 fatty acid series, n-3: omega 3 fatty acid series, AI: atherogenic index, TI: thrombogenic index, DFA: desirable fatty acids, LPS: lipid preventive score, HPI: health-promoting index.
SCN: Regular soft white cheese, SCO: Soft white cheese fortified with flaxseed oil, RSCO: Reduced soft white cheese fortified with flaxseed oil, FO: Flaxseed oil.

($P < 0.05$) increased the level of omega-3 fatty acids in the final product.

The most important fatty acids for human health are: C18:1, C18:2 and C18:3. In the obtained data, there was a significant difference in the content of the polyunsaturated fatty acid C18:3 between the control and cheeses containing FO. Total amount of long-chain fatty acids (above C18) in the cheese samples were significantly ($P < 0.05$) higher compared to the control.

To evaluate the nutritional value of lipids, the different sums of fatty acids and lipid health indices are presented in Table III. Atherogenicity index (AI), thrombogenicity index (TI), lipid preventive score (LPS) and ratio of n6/n3 significantly decreased with the incorporation of FO, while the amount of desirable fatty acids (DFA) and health-promoting index (HPI) increased significantly in fortified cheeses.

According to Lima et al. [22], there are currently no criteria for the AI and TI of dairy products, although lower indices are regarded to be better for human health. Lower AI and TI are thought to translate into more anti-atherogenic fatty acids and better disease prevention profiles. Our results agreed with Caroprese et al. [46].

In SCO and RSCO, the Atherogenic and Thrombogenic indices, as well as the ratio of n-6 to n-3, were lower; indicating that the nutritional characteristics of cheeses made with FO had improved. The balance of n-6 and n-3 PUFA in the diet, in particular, is important in the prevention of numerous ailments, including coronary artery disease [47].

The polysaturated fatty acid/Monounsaturated fatty acid (PUFA/SFA) ratio was found to be 0.05, 0.43, 0.39 in the control, SCO and RSCO respectively. Short-chain fatty acids (i.e., C4-C10) in ester form play a vital role in milk fat, giving it its distinctive flavour and aroma. Short-chain fatty acids in free form, on the other hand, are responsible for the rancid flavour [48]. According to Abbas et al. [9], Nutritional guidelines recommend a PUFA/SFA ratio between 0.4-1.0 and ω6/ω3 PUFAs less than 4 to prevent cardiovascular disease.

Dietary recommendations for omega-3 fatty acids can be obtained from the diet by the consumption of foods rich in these fatty acids. According to Joint WHO/FAO 2010, the daily recommended intake of omega-3 fatty acids should be at least 250 mg/day for a healthy life [49].

CHOLESTEROL CONTENT

Significant differences in cholesterol content ($p < 0.05$) were found between cheese samples. From the data presented in Table IV, it is apparent that the cholesterol content decreased with the decreasing fat content. The highest cholesterol content among all cheeses analysed was that found in SCN (133.7 mg/100g) cheese due to their high fat content and as expected, the cholesterol level in regular soft white

Table IV - Cholesterol content of soft white cheeses fortified with flaxseed oil

Samples	Cholesterol mg/100g ± SD	Fat g/100g ± SD	Cholesterol/fat
SCN	$133.7^{a} \pm 0.10$	$20{,}06^{a} \pm 0.08$	6.66
SCO	$131.5^{b} \pm 0.14$	$17{,}96^{b} \pm 0.08$	7.32
RSCO	$123.8^{c} \pm 0.02$	$16{,}46^{c} \pm 0.08$	7.52

Values are means of triplicate determinations ±SD
a,b,c lower case letters within each column indicate statistically significant differences (P <0.05)
SCN: Regular soft white cheese, SCO: Soft white cheese fortified with flaxseed oil, RSCO: Reduced soft white cheese fortified with flaxseed oil

Table V - Sensory characteristics of regular and supplemented soft white cheeses fortified with flaxseed oil.

Samples	Appearance	Color	Aroma	Flavor	Softness	Texture	Overall Acceptability
SCN	$8.05^{a} \pm 1.27$	$8.1^{a} \pm 1.11$	$7.4^{a} \pm 1.46$	$6.75^{a} \pm 2.02$	$7.25^{a} \pm 1.2$	$7.3^{a} \pm 1.38$	$7.55^{a} \pm 1.19$
SCO	$7.4^{a} \pm 1.23$	$7.4^{a} \pm 1.18$	$7.00^{a} \pm 2.00$	$5.85^{a} \pm 1.72$	$6.3^{a} \pm 1.62$	$6.4^{a} \pm 1.60$	$6.45^{b} \pm 1.57$
RSCO	$7.75^{a} \pm 1.40$	$7.8^{a} \pm 1.5$	$6.2^{a} \pm 2.52$	$5.2^{a} \pm 2.19$	$6.6^{a} \pm 2.30$	$6.5^{a} \pm 1.96$	$5.3^{c} \pm 2.08$

Values are means of triplicate determinations ±SD.
^{a,b,c} lower case letters within each column indicate statistically significant differences (P <0.05)
SCN: Regular soft white cheese, SCO: Soft white cheese fortified with flaxseed oil, RSCO: Reduced soft white cheese fortified with flaxseed oil

cheese containing milk fat was significantly higher because its main source of cholesterol is animal fat. The cholesterol observed in fortified samples, which was almost 131.5 mg/100g in SCO and 123.8 mg/100g in RSCO, could be originated from milk serum [41]. The cholesterol contents were highly correlated with the fat levels ($r = 0.919$). Namely, the cholesterol/fat ratio was the lowest in the regular soft white cheese (6.66) in contrast to RSCO cheese (7.52). In addition, a trend of increasing cholesterol/fat ratio with decreasing fat content suggests that the addition of FO may reduce the cholesterol content. Our finding was in line with Donmez et al. [43] and Abou Jaoudeet al. [50] and disagreed with Andrikopoulos et al. [51] and Arslan et al. [48]. According to Ullah et al. [52], the addition of chia oil to fortified cheddar cheese resulted in a drop in cholesterol and an increase in ALA fatty acid.

Arslan et al. [48] found that Turkish white cheese supplemented with corn oil had a better fatty acid profile than the control cheese, indicating a rise in the ratio of PUFA/SFA and a decrease in cholesterol level. The consumption of dairy products with lower AI values leads to a decrease of the total cholesterol and LDL-cholesterol in human blood plasma [53].

SENSORY EVALUATION

Sensory profile of FO-incorporated white soft cheeses is presented in Table V. No significant difference ($p > 0.05$) was observed in mean scores for appearance, colour, aroma, flavour, softness and texture between the control and FO-fortified cheese samples.

The control sample exhibited the highest scores in terms of all sensory attributes among the examined cheeses samples. This was possibly because fat plays an effective role in the colour, taste, flavour and texture [54]. Similar trend was also observed for aroma and flavour scores which were higher in SCO than RSCO. Moreover, RSCO received higher scores in terms of appearance, colour, softness and texture as compared to SCO.

Flavour ratings were lower in FO-incorporated samples than in the control. This could be due to the breakdown of carbohydrates into lactic acid and the release of taste components like acetaldehyde, or the breakdown of fat into volatile fatty acid [55].

All cheese samples were characterised with white colour, milk odour, salty taste, soft body and grittiness during mastication. Nevertheless, all cheese samples were judged to be acceptable products by the panellists. During storage, no off-flavours or bitterness were observed in any of the cheeses. As a result, PUFA enrichment has no negative impact on customer acceptability. Similar results were obtained by Hassan et al. [56].

There were significant ($P \leq 0.05$) differences in the overall acceptability between control and fortified white cheese samples. According to the panellists, full-fat cheese (SCN) showed a significantly higher overall acceptability compared to SCO and RSCO. Our results are in harmony with Sulejmani et al. [8], who investigated the effect of vegetable fat on the texture, colour and sensory properties of Macedonian white brined cheese.

Low-fat cheeses fortified with FO (RSCO) were characterised by a lower overall score compared to all other cheese samples. This could be due to the significantly higher salty taste and lower fat content in the low-fat cheese. Our results disagree with those reported by Mahrous [27] and Felfoul et al. [57].

Hassan et al. [56] reported that the effects of FO in Egyptian lactating buffalo and cow diets on milk and soft cheese quality were minimal, with no significant changes in soft cheese sensory and textural attributes.

CONCLUSION

This study was carried out to characterise the changes that occur in cheese formulations containing FO and compare them to control cheeses (made with full fat milk) and skim milk cheeses, as well as to improve the nutritional and therapeutic value of processed cheeses using FO as a functional element due to its high nutritional and health value. Based on these findings, FO could be recommended as a useful ingredient in cheese production due to its high content of ALA. The Dietary recommendations for omega-3 fatty acids can be obtained from the diet by the consumption of foods rich in these fatty acids. According to Joint WHO/FAO 2010, the daily recommended intake of omega-3 fatty acids should be at least 250 mg/day for a healthy life. The fortified soft white cheese with FO showed an increase of ALA content (17.67% of total fatty acids) compared to control (0.51% ALA). It is recommended to take foods that supply omega-6 and omega-3 in an ideal ratio of 4:1 to prevent the development of chronic diseases such as cardiovascular disease. Furthermore, by combining dairy products with vegetable oils, it is possible to boost the nutritional value of fat in the diet. Indeed, today's market includes cheeses with fat content as low as 3%. As a result, reduced-fat cheeses have a good chance of becoming as enticing and popular as full-fat cheeses. To decrease lipid oxidation of FO during homogenisation, a future study could focus on microencapsulation or on the use of edible films and coatings.

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