Canrea Journal: Food Technology, Nutritions, and Culinary, 2024; 7 (2): 199–212 OPEN ACCESS

e-ISSN : 2621-9468

Type of the Paper (Article)

Physicochemical characteristics, fatty acids profile, health lipid Indices and consumer acceptability of processed cheese prepared from camel milk blended with avocado powder

Rehab F. M. Ali

Department of Food Science and Human Nutrition, College of Agriculture and Food, Qassim University, 51452, Buraydah, Saudi Arabia

Abstract

The aim of the current investigation was to evaluate the impact of different quantities of avocado fruit pulp powder (AFPP) (0, 5, 10, 15, and 20%) on the sensory properties, physicochemical properties, and fatty acid profile of Camel's milk processed cheese (CMPC). CMPC cheese represents the control sample without AFPP addition. At ratios of 100:0, 95:5, 90:10, 85:15, and 80:20, AFPP was used to substitute CMPC cheese (%, w/w). Standard official methods were used to analyze the proximate composition, mineral content, fatty acid profile, health lipid indices, as well as consumer acceptability of CMPC, AFPP, and binary mixtures of them. AFPP was rich in fat, protein, ash, and fibers (58.18, 8.19, 7.48, and 7.00%, respectively). CMPC is mainly composed of moisture (63.03 %), with 23.9%, % of crude protein, 9.15 % of lipids and3.92 % ash. Fat, fiber, ash and energy contents of fortified cheese samples increased significantly with the addition of AFPP. No significant differences were recorded in protein between control cheese samples and those cheese samples containing AFPP. The results also revealed that the K, Mg, Fe, and Zn content in CMPC cheese samples enriched with 20% AFPP were about 2.41,1.18,1.72, and 1.30-fold higher, respectively, when compared to control cheese without any addition of AFPP. In fortified cheese samples, the amounts of oleic, linoleic, and linolenic acids significantly increased as the AFPP dosage increased; however, the amounts of myristic, palmitic, and stearic acids decreased as the AFPP concentration increased. The reduction in atherogenic and thrombogenic indices of CMPC cheese samples with different concentrations of AFPP demonstrate the nutritional advantages of CMPC cheese enriched with avocado powder. The sensory evaluation results indicated that all processed cheese samples in the current investigation were acceptable and received high overall acceptability scores ranged from76.19 to 84.60.

Article History
Received December 21, 2023
Accepted December 28, 2024
Published December 31, 2025

Keywords
Food intake, Food Processing, Antioxidant, Polyphenols, Public Health, Dietary Supplement, Fatty Acid.

1. Introduction

The food supply must include both processed and fresh items. Processed foods promote both nutritional safety (ensuring that food quality satisfies human nutrient demands) and food security (ensuring that there is enough food available). Nutritionists and food scientists are diligently working really hard to develop healthy foods. The incorporation of nuts, fruits, vegetables, herbs, and spices into processed foods became an effective way to improve and enhance their nutritional qualities due to the fact that they have a wide range of nutrients (1,2).

* Correspondence : **Rehab F. M Ali** reh.ali@qu.edu.sa

ISSN 2621-9468 online, DOI 10.20956/canrea.v7i2.1221

Camels have been domesticated for a very long time, and they provide food (meat and milk) and fabrics (fiber and hair strands) as livestock. Camels can contribute to economic growth and food security through the production of meat, dairy products, as well as additional products (3). Camel profitability in desert environments is ensured by their comparative advantages in their ability to adapt and remain productive under hard environmental circumstances (4). Previous study has shown that camel and camel milk production contributes significantly to local and national economies, as well as individual livelihoods (5). The camel milk business has a lot of opportunities for improvement. to strengthen the livelihoods and economic position of communities of pastoralists (6). Camel milk (CM) is known as the "white gold of the desert" because to its nutritional value (7). Camel's milk has a pH range of 6.2 to 6.5, is white and opaque, has a slightly salty taste, has a very low-fat content of 96% triglycerides, and has about 30 mg of cholesterol per 100 grams of dry matter (8). Camel milk is extremely rich in vitamins B1, B2, and C (9) The amount of vitamin C in camel milk is between three and five times more than in bovine milk, in accordance with studies conducted by Kamal and Karoui (10). Camel's milk and fermented camel milk (FCM) has been shown to have antibacterial, antioxidant, anticancer, antihypertensive, and anti-diabetic properties (11). The antidiabetic activity of camel dairy products might be correlated with the inhibition of numerous metabolic enzymes corresponding to the progression of diabetes, such as dipeptidyl peptidase IV (DPP-IV), an enzyme that degrades the insulin-secreting incretin hormones glucagon-like peptide (GLP) and gastric inhibitory polypeptide (GIP), α-amylase, and α-glucosidase (12).

Avocado (*Persea americana*) fruit (AF) is typically consumed in its ripe form as a table vegetable (fresh cut) or used in recipes like mayonnaise and margaritas. Processed avocado products include frozen slices and pulp, packaged guacamole and avocado oil. Due to their exceptional health and distinctive flavor and scent, these fruits have a significant commercial value (13). Avocado fruits contain proteins, carbohydrates, lipids, vitamins (B2, B3, B5, B6, B7, B9, C, E, and so on), minerals (calcium, copper, iron, magnesium, manganese, and phosphorus), and natural colors (chlorophylls and carotenoids), which contribute to their nutritional value (14). According to Dreher and Davenport (15), avocado oil contains 71% monounsaturated fatty acids, 13% polyunsaturated fatty acids, and 16% saturated fatty acids, which contributes to maintain balanced blood lipid profiles and increases absorption of phytochemicals and fat-soluble vitamins. Lye et al. (14) described and summarized the therapeutic properties of avocado fruits, which include antioxidant, antitumor, hypoglycemic, antiatherosclerotic, antimicrobial, as well as anti-inflammatory activities. On the contrary, avocado is a climacteric fruit with a high moisture content that seems to be extremely difficult to store, resulting in a lower shelf life and higher postharvest loss (16). As a consequence, employing avocados as fresh commodities made it difficult to give both economic value and trade stability.

Avocados that have been preserved and processed may have an extended shelf life, retain more nutritional quality, and have a higher commercial and economic value. Different novel processed food products can also be developed and commercialized (17). Additionally, due to their wide range of sensory attributes, including flavor and texture, processed cheeses have become more popular and consumed by both children and young people. As a result, it is extensively utilized in a wide range of applications (in fast-food and catering chains), either raw or processed cheese (18). Processed cheese (PC) and processed cheese spread (PCS) are cheese-based food items made by blending, shearing, and emulsifying natural cheese(s) of different maturity dates in the presence of appropriate emulsifying salts (ES). In addition, dairy product (such as cream, butter, and anhydrous milk fat as well as different milk powder blends) and nondairy substances (such as stabilizers, preservatives, acidifying agents, and NaCl) are employed to comply with the finished product's specifications (19,20).

In order to produce processed cheese, both dairy and non-dairy components can be blended with natural cheeses. Several non-dairy components have been employed, including mushrooms, vegetables, wheat fiber, egg protein, meat, fruit juices and pulp, almonds, as well as oats (21). When compared to control samples, processed cheese (PC) samples containing tomato powder (PCTs) had higher levels of proteolysis degree phenolic and lycopene concentrations, as well as antioxidant capacities (22). Adding denatured whey protein paste (DWPP) into cheese dropped saturated fatty acid levels while increased unsaturated fatty acid (USFA) levels, which resulted in a reduction in cheese hardness at high doses of DWPP due to the low melting points of USFA. The results also concluded that the that supplementing Gouda cheese with 1 or 2% DWPP increased the textural attributes (23).

At present, the features of processed cheese by employing avocado fruit pulp powder (AFPP) have not been evaluated. Therefore, the objective of the current study was to determine the impact of adding different levels avocado fruit pulp powder (AFPP) (0, 5, 10, 15 and 20%) on the sensory properties, physicochemical properties, and fatty acid profile of Camel's milk processed cheese CMPC.

2. Materials and Methods

2.1. Materials

Six kilograms of Camel's milk Edam cheese and AF (*Persea americana*) were purchased from a local market in Giza, Egypt's Maadi - City Center branch, all reagents and chemicals that were used in this study were of analytical grade.

2.2. Methods

2.2.1. Preparation of AFPP

Avocado fruit were washed with tap water, peeled. The fruit pulp was chopped into small pieces (2×2×2 cm). The Small pieces of pulp fruit were frozen at - 40°C for 18 hours and then freeze-dried for 5 days using freeze-dryer (Labconco Corporation, Kansas City, MO, USA). The freeze-dryer's shelf temperature was 40 °C and the chamber temperature was 20 °C (i.e., the avocado pulp sample was frozen at - 40 °C and subsequently dried to 20°C) with an operating pressure of 200 Pa. The freeze- dried pulp fruit sample was kept in a brown bottle at 4 °C until use.

2.2.2. Preparation of CMPC Spread

Camel's milk Edam cheese was used to produce camel's milk processed cheese (CMPC) spread according the procedures described by Rafiq and Ghosh (21). In brief, chopped Camel's milk Edam cheese was blended with distilled water (20% of the cheese weight) and 3% potassium phosphates (emulsifying salt) in a pilot-scale cheese cooker (Thermaflo, Takaro, Palmerston, New Zealand). The mixture was cooked in the cheese cooker for 5 minutes at 90±5°C with constant stirring (1500 rpm) until the cheese mass became homogeneous. AFPP powder was added to this basic mixture in various ratios (0, 5%, 10, 15 and 20 % w/w), and each formula was heated for 5 minutes at 80 ±5°C with constant mixing. The hot melted cheese was placed individually in 500 cm3 glass containers, cooled in a 15 °C cooled incubator for two hours, and then stored in a refrigerator (4±1°C) for further investigation.

2.2.3. Preparation of CMPC Spread

Moisture content, protein content, ash, and crude fiber contents of CMPC samples were assessed according to AOAC (24), methods 925.09 B, 950.36, 930.22and 950.37, respectively). Total crude lipids were determined using Soxhlet method based on Ling (25) procedures. Total carbohydrate content was calculated by subtraction of the sum of the crude protein, total fat, moisture, and ash from 100g (26).

2.2.4. Caloric Value

The following equation was used to compute the energy value (kcal/100 g) (26).
Energy (kilocalories per 100 grams) = [9(lipids%) + 4 (proteins%) + 2(fiber%) + 4(carbohydrates%)].

2.2.5. Mineral's Content

The mineral contents in a diluted solution of the ashed samples were determined using an atomic absorption spectrophotometer (3300 PerkinElmer, Spectra Lab Scientific Inc. 38 McPherson St. Markham, ON, CanadaL3R 3V6), using the method described by Althwab et al., (27)

2.2.6. Fatty Acid Composition of Cheese Samples

The fatty acids were analyzed and qualitatively determined using capillary gas chromatography (HP 6890, Agilent Technologies, Inc. 2850 Centerville Road Wilmington, DE 19808-1610), and the results were presented as relative area percentages (28).

2.2.7. Health Lipid Indices

The health lipid indices of the CMPC samples were assessed using various fatty acid ratios and combinations. The atherogenic (AI) and thrombogenic (TI) indices and Hypocholesterolemic Fatty Acids (DFA), were determined using the Ulbright and Southgate (29) equations. as follows:

$$AI= \frac{C12:0 + 4 \times C14:0 + C16:0}{MUFA + PUFA} \quad (1)$$

$$TI= \frac{(C14:0 + C16:0 + C18:0)}{(0.5MUFA + 0.5\ \omega\text{-}6\ PUFA + 3\ \omega\text{-}3PUFA + \omega\text{-}3/\omega\text{-}6)} \quad (2)$$

$$DFA= UFA+C18:0 \quad (3)$$

Where MUFA, Monounsaturated Fatty Acids; PUFA, Polyunsaturated Fatty Acids, UFA, Unsaturated fatty acids (UFA) are formed by integrating polyunsaturated (PUFA) and monounsaturated (MUFA) fatty acids.

2.2.8. Organoleptic Properties of CMPC Samples

To perform the sensory evaluation for the CMPC samples, 30 semi-trained panelists (22 females and 8 males) were recruited from the graduate students and staff of the Department of Food Science and Human Nutrition, College of Agriculture and Food, Qassim University, Buraydah, Saudi Arabia. Three-digit codes were used for labeling cheese samples. A number of factors were evaluated for reaching the final decision, including flavor (30), body and texture (30), color and appearance (20), consistency (10), mouth feel (10), and overall acceptance (100). During the sensory evaluation, bottled drinking water were provided to keep the mouth clean in between CMPC cheese samples.

2.2.9. Statistical Analysis

The results of each analysis were performed in five replicates, and they were presented as mean values± standard deviation. One-way analysis of variance (ANOVA) was used to statistically evaluate the difference between the mean values ($p \leq 0.05$).

3. Results and Discussion

3.1. Chemical Content

Table 1 illustrates the proximate composition of AFPP and CMPC enriched with various AFPP concentrations (0, 5%, 10, 15, and 20% w/w). The moisture value of AFPP was 5.68%; the low moisture level allows for easier storage, maintains shelf life, and ensures the safety of food products (30). The freeze-drying product maintains its form, is easily rehydrated, and can inhibit microbe growth, freeze-drying is the best method for dehydrating avocado fruits (31). AFPP contained high quantities of fat, protein, ash, and fibers (58.18, 8.19, 7.48and 7.00 %, respectively). These results are consistent with those of Casteneda-Saucedo et al. (31), who reported that rainfed freeze-drying avocado pulp has 68.78% fat, 11.24% ash, 6.30% protein and 6.27% fiber. Based on these data, AFPP can be used as a source of fat, protein, ash, and fiber. CMPC is mainly composed of moisture (63.03 %), with 23.9%, % of crude protein, 9.15 % of lipids and 3.92 % ash. These findings complied with those reported by Abbas et al., (18). As consequently, when CMPC is supplemented with different amounts of AFPP, incorporating AFPP as a recommended additive could enhance its nutritional qualities. The proximate compositions (nutritional quality) of the CMPC enriched with different AFPP quantities (0, 5%, 10, 15, and 20% w/w) are shown in Table 1. The incorporation of AFPP affected the chemical properties of CMPC significantly (Table 1). Moisture content was significantly lower in the processed cheese samples supplemented with AFPP than in the control without AFPP addition. The moisture content decreased significantly from 63.03 % in control cheese samples to 60.13, 57.15,54.39 and 51.48 in those CMPC samples supplemented with 5, 10, 15, and 20 % respectively. Increasing AFPP substitution significantly ($P \leq 0.05$) enhanced the fat content of CMPC samples, as expected (Table 1). The highest fat level (18.83%) was discovered in CMPC samples supplemented with 20% AFPP, whereas the lowest (9.15%) was detected in control samples without fortification. The fat content of CMPC samples increased significantly as AFPP levels in the recipes increased ($p \leq 0.05$). The percentage of fat increases in enriched cheeses ranged from 26.77% to 105.79%. These increases in fat content of treated cheese samples could be due to the high lipid content of AFPP. AFPP contains 58.18% fat on dry weight (Table 1. Avocados have a high total fat content (15.4 g/100 g, as fresh weight basis), which is dominated by MUFA (9.8 g/100 g), a high phytosterol content (57 mg/100 g), and no cholesterol (32). Cheese analogues are created by combining fat and/or protein sources other than those found in milk with a flavor system that is as close to the real product as possible. An appropriate processing process capable of incorporating these ingredients to achieve the desired textural and functional qualities must also be developed (33).

Protein content varied from 20.75 to.23.90% in cheese samples. There were no statistically significant differences in protein content between control cheese samples (23.90%) and those enriched with 5% AFPP (23.13%). Protein content of enriched cheese samples decreased significantly when CMPC was replaced with 10%, 15%, and 20% AFPP. The addition of 15 and 20% AFPP powder into cheese blends resulted in significant reductions in protein content (21.53 and 20.75%) compared to the protein content of the control sample (23.90%). These decreases are consistent with the findings that AFPP had a high concentration of lipids and a low concentration of protein (Table 1).

The ash level of fortified cheese samples with various amounts of AFPP was higher than that of the control (unfortified cheese sample). The ash level of CMPC samples with 20% AFPP supplementation was the highest (4.65 g / 100 g), meanwhile the control (with no AFPP supplementation) was the lowest (3.92 g/ 100). Simultaneously, increasing the amount of AFPP fortification significantly ($p \leq 0.05$) increased the ash content of fortified cheese. Avocado (*Persea americana*) fruit can be considered as a good source of minerals, it contains high amount of ash ranged 9.40 to 11.24 % (31). The findings are consistent with those presented by Mehanna et al., (34), who found that adding tomato juice to processed cheese enhanced its ash levels. Fiber content (g/100 g) of fortified cheese samples ranged from not-detectable level to 1.40 %. Cheese samples with various amounts of AFPP had significantly higher levels of fiber content than control samples without AFPP addition. Fiber content of the fortified cheese samples can be arranged in the decreasing order as follows: Cheese with 20 % AFPP > Cheese with 15 % AFPP > Cheese with 10 % AFPP > Cheese with 5 % AFPP > control samples without AFPP addition. Avocado fruit is a great source of dietary fiber (31). According to the research, "fiber has emerged as an important dietary component in the prevention of chronic diseases. High fiber consumption lowers the risk of cardiovascular disease, certain cancers, hypertension (high blood pressure), diabetes, and malnutrition (26).

The carbohydrate content of enriched cheese samples ranged from not-detectable level to 1.83 %. Substituting AFPP powder into CMPC cheese resulted in considerable increases in carbohydrate content of cheese samples. The addition of 15 and 20% AFPP powder into cheese blends resulted in significant increases in carbohydrate content (1.39 and 1.83 %) compared to the control sample without AFPP inclusion. These increases are consistent with the findings that AFPP powder included a considerable quantity of carbohydrates (Table 1). The energy content of the cheese samples ranged from 56.11 to 177.46 (kcal / 100 g). Substituting CMPC cheese with different quantities of AFPP powder results in significant increases in energy content. Cheese samples enriched with 5-20% AFPP powder contain considerably higher energy than control samples. The greatest energy values (145.64 and177.46 kcal) were found in CMPC cheese samples enriched with 15% and 20% AFPP powder, respectively. These calorie increases could be attributed to the AFPP powder's high fat and protein content Table 1). In compared to other tropical fruits, avocados are rich in calories. It has a high nutritional value since it contains a significant amount of proteins (1.11 to 1.75 g per 100 g), lipids (4.8 to 10.15 g per 100 g), and carbohydrates (7.3 to 11.54 g per 100 g) (35). According to Othman et al., (36), who reported a similar conclusion, energy content increased significantly as dietary lipids content increased. Previous studies discovered that muffins fortified with avocado puree exhibited significant increases in moisture, ash, and carbohydrate when compared to the control sample (36), which is similar with the current findings. The pH value of cheese samples ranged from 6.7 to 6.8. There were no statistically significant changes in pH value between fortified and unfortified cheese samples.

These results indicate that the addition of AFPP powder into CMPC cheese samples showed significant improvements in ash, fat, fibers, carbohydrates as well as energy content, while protein content was slightly reduced due to AFPP powder addition.

Table 1. Proximate composition (g/100g), energy value pH values of AFPP and CMPC enriched with different amounts of AFPP

Component	AFPP	CMPC	CMPC + AFPP			
			(95:5%w/w)	(90:10%w/w)	(85:15%w/w)	(80:20%w/w)
Moisture	5.68^{f}±0.27	63.00^{a} ±2.43	60.16^{b}±2.98	57.30^{c}±1.96	54.43^{d}±1.95	51.50^{e}±2.13
Crude protein	8.19^{e}±0.64	23.90^{a}±1.09	23.13^{ab}±1.23	22.32^{b}±1.46	21.53^{c}±1.12	20.75^{d}±0.87
Fat content	58.18^{a}±1.07	9.15^{e}±0.77	11.6^{d}±0.84	14.05^{c}±1.02	$16.50^{bc±}$0.94	18.83^{b}±0.88
Ash	7.48^{a}±0.53	3.92^{de}±0.21	4.10^{d}±0.22	4.28^{c}±0.31	4.45^{b}±0.35	4.65^{b}±0.33
Dietary fibers	7.00^{a}±.91	ND	0.35^{d}±0.03	0.70^{c}±0/06	1.05^{bc}±0.05	1.40^{b}±0.06
Total carbohydrates	9.15^{a}±0.86	ND	0.46^{e}±	0.92^{d}±0.08	1.39^{c}±0.11	1.83^{b}±0.13
pH	6.8^{a}±0.02	6.68^{a}±0.04	6.69^{a}±0.03	6.69^{a}±0.03	6.70^{a}±0.01	6.70^{a}±0.06
Energy value (kCal/100 g)	646.9a±0,98	56.11f±0.67	87.14^{e}±1.24	113.67^{d}±1.46	145.64^{c}±0.96	177.46^{b}±1.22

Values are mean ± SD of five replicates.
Values with different superscript letters in the same row are significantly different ($p \le 0.05$).
ND: not detected.
AFPP Avocado fruit pulp powder, CMPC Camel's milk processed cheese.

3.2. Mineral Content of CMPC Cheese Samples

Mineral's content of CMPC cheese samples fortified with different levels of AFPP (on dry weight basis) are presented in Table 2. The mineral content of CMPC cheese samples was completely affected by modifying the AFPP powder blending ratio. Generally, the content of K, Mg, Fe, and Zn of CMPC cheese samples supplemented with different amounts of AFPP increased significantly ($p \le 0.05$) as AFPP replacement levels increased (Table 2). This finding could be due to the high contents of mineral elements in AFPP. Avocado fruits were shown to be rich in minerals such as calcium copper, iron, magnesium, manganese, and phosphorus (14). The highest quantity of these micro- and macro elements was detected in CMPC cheese samples supplemented with 20% AFPP, whereas the lowest values of these elements were observed for control cheese samples (without AFPP supplementation). The results also revealed that the K, Mg, Fe, and Zn content in CMPC cheese samples enriched with 20% AFPP were about 2.41,1.18,1.72, and 1.30-fold higher, respectively, when compared to control cheese without AFPP addition. This finding confirms with the results presented by Mohamed et al. (37) who showed that processed cheese analogue enriched with spirulina powder at levels of 1, 2 and 3% had better mineral content than control cheese without additives. Similarly, Yadav and Mishra (38) discovered that spreadable cheese supplemented with mushroom powder contained more micro- and macro-elements than control cheese samples without supplementation.

Table 2. Mineral contents (mg 100 g^{-1}) of AFPP and CMPC enriched with different amounts of AFPP

	AFPP	CMPC	CMPC + AFPP			
			(95:5%w/w)	(90:10%w/w)	(85:15%w/w)	(80:20%w/w)
Na	59.90^{e}±1.34	512.30^{a}±7.88	488.57^{ab}±8.99	464.84^{b}±7.34	441.11^{c}±12.08	417.38^{d}±7.00
Ca	23.20^{e}±2.88	526.30^{a}±9.18	500.01^{ab}±11.23	473.73^{b}±9.13	447.44^{c}±16.71	421.15^{d}±4.88
K	584.00^{a}±13.09	72.20^{b}±1.96	68.61^{b}±0.97	65.02^{c}±3.74	61.44^{d}±3.00	57.85e±2.98
Mg	37.70^{a}±0.87	19.40^{b}±1.22	18.44^{bc}±2.08	17.47^{c}±2.08	16.51^{cd}±0.95	15.54^{e}±1.08
Fe	0.56^{a}±0.09	0.11^{b}±0.00	0.12^{b}±0.00	0.12^{b}±0.02	0.12^{b}±0.00	0.12b±0.00
Zn	0.44^{a}±0.03	0.18^{b}±0.00	0.17^{b}±0.00	0.17^{b}±0.03	0.16^{bc}±0.03	0.15^{c}±0.02
Mn	0.10^{d}±0.00	0.35^{a}±0.04	0.34^{a}±0.06	0.32^{b}±0.00	0.30^{bc}±0.00	0.29^{c}±0.00
Cu	0.13^{e}±0.00	2.40^{a}±0.08	2.28^{a}±0.00	2.16^{b}±0.00	2.04^{c}±0.00	1.92^{d}±0.00

Values are mean ± SD of five replicates.
Values with different superscript letters in the same row are significantly different ($p \leq 0.05$).
ND: not detected.
AFPP Avocado fruit pulp powder, CMPC Camel's milk processed cheese

3.3. The Fatty Acid Profile

The fat content of CMPC cheese samples supplemented with various amounts of AFPP% (w/w) is shown in Table 3. Generally, the fat content of CMPC samples ranged from 9.15 to 18.83. In this regard, Engberink et al. (40) classified high- and low dairy foods based on their total fat content: low-fat dairy: milk and milk products with less than 2.0 g fat per 100 g, cheese products with less than 20 g fat per 100 g; high-fat milk and cheese: milk and milk products with more than 3.5 g fat per 100 g, cheese products with more than 20 g fat per 100 g. As a result, the CMPC samples under investigation are high-fat dairy foods. Therefore, to reduce the risk of CVD through maintaining appropriate plasma lipids and lipoprotein cholesterol levels, exclusively reduced and fat-free milk as well as dairy products are recommended as part of a balanced diet (39).

Fatty acids are categorized into three types: saturated (SFA), mono-unsaturated (MUFA) and polyunsaturated (PUFA) fatty acids. Unsaturated fatty acids, on the other hand, are separated into omega groups, with omega-9 believed to be non-essential for humans and omega-3 and -6 considered to be essential, because the latter cannot be synthesized by mammalian and must thus be supplied through diet (40). Table 1 shows the Fatty acid compositions of CMPC cheese samples fortified with various doses of AFPP. The predominant fatty acids in CMPC fats (100:0, with no AFPP addition) were oleic (27.1%), palmitic (26.8%), stearic (14%), palmitoleic (cis-9-hexadecenoic) acid (13.22%), and myristic (9.9%)., whereas the predominant fatty acids in AFPP oil were oleic acid (68.08%), palmitic (15.4%), palmitoleic (cis-9-hexadecenoic) acid (7.33%), and linoleic acid (7.19%), respectively. Avocado oil contains a high concentration of oleic acid, antioxidants, and phytosterols (41).The results revealed that the concentrations of oleic (cis-9-octadecenoic) acid (C 18:1), linoleic (9,12-octadecadienoic) acid (C 18:2), and linolenic (9,12,15-octadecatrienoic) acid (C 18:3) increased significantly with increasing the AFPP levels in the cheese blend formulations; while the quantities of myristic (tetradecanoic) acid (C 14:0), palmitic (hexadecanoic) acid (C 16:0) and stearic (octadecanoic) acid (C 18:0) dropped as the AFPP concentration was increased. Supplementing cheese samples with various quantities of AFPP% (w/w) led to produce CMPC cheese with significant increases in monounsaturated and polyunsaturated FAs, mainly as oleic and linoleic acids, respectively. Avocado oil's fatty acid composition is mostly composed of unsaturated fatty acids (79.7%) and a little amount of saturated fatty acids, this indicates the high concentration of poly and mono unsaturated fatty acids that are favorable to health, since the triglycerides found in avocados are not fats but oils that remains liquid at room temperature (31). According to Dreher and Davenport (15), 'Hass' avocado oil contains 71% monounsaturated fatty acids, 13% polyunsaturated fatty acids, and 16% saturated fatty acids, promoting balanced blood lipid profiles and increasing the absorption of fat-soluble vitamins and phytochemicals. According to recent nutritional guidelines, the majority of people should limit total fat consumption to less than 30% of total calories and saturated fat consumption to less than 10% of total calories. For patients with high LDL cholesterol or cardiovascular disease, the American Heart Association (AHA) recommends lowering saturated fats to 7% of total calories. To achieve a more healthful dietary patterns, modern nutritional guidelines advise people to consume more fruits, vegetables, and grains while reducing the type and amount of fat they receive (42,43).

3.4. Health Lipid Indices

Furthermore, the PUFA/SFA and PUFA n-6/n-3 ratios, hypocholesterolemic and hypercholesterolemic fatty acid levels, as well as atherogenic and thrombogenic indices have become some of the key metrics for assessing the nutritional value and healthiness of diets (44). Therefore, the present study focused on identifying certain quality indicators associated with lipid health (such as AI, TI, and DFA). The atherogenic index (AI) is calculated as sum of the amounts of saturated fatty acids (C12:0 + 4×C14:0 + C16:0) and then dividing that amount by the total concentration of unsaturated fatty acids (29).

Generally, Atherogenic and thrombogenic indices were reduced in CMPC cheese samples supplemented with various doses of AFPP, confirming the improvement of nutritional aspects of CMPC cheese supplemented with avocado powder. 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 (45). The current study indicates also that supplementation of CMPC cheese samples with 20% AFPP was able to reduce the atherogenic index andhrombogenic index by 14.51% and 16.93 %. respectively. According to Paszczyk and uczyska (46), dairy products may offer protection against coronary heart disease (CHD) if their atherogenic index (AI) is low. Table 3. shows that DFAs values of produced cheese samples ranged from 60.27 to 65.14. Cheese fortified with AFPP powder showed a higher DFAs values than control cheese. The highest DFAs value (65.14) was recorded for CMPC cheese samples enriched with AFPP 20% (w/w), meanwhile, the lowest DFAs value was found in control samples without AFPP addition. Generally, increasing the amount of AFPP fortification significantly ($p \leq 0.05$) increased the DFAs value of fortified cheese. Higher dietary intakes of unsaturated fatty acids have been associated with higher amounts of DFA in milk, according to Osmari et al., (47). DFAs are anti-atherogenic because they include stearic acid (C18:0) and unsaturated fatty acids, both of which reduce plasma cholesterol and triacylglycerols. Recent investigations has demonstrated that avocado seed extract has anti-dyslipidemic potential, which could be effective in the treatment of hypertension and other dyslipidemic diseases (48). Avocado oil has acquired popularity in the human diet as a result of its high concentration of MUFA (65.3%) and beneficial health effects in terms of anti-inflammatory characteristics and cardiovascular disease. The concentration of the most significant PUFA, 18:3 (n-3), in avocado oil and olive oil was nearly same (0.73 and 0.78%, respectively (49).

Table 3. The fatty acid profile of AFPP and CMPC enriched with different amounts of AFPP

Fatty acid (%)	AFPP	Samples CMPC %+ AFPP % (w/w)				
		100:0	95:5	90:10	85:15	80:20
C 4: 0 Butyric acid	0.00[e]	0.79[a]	0.73[b]	0.70[b]	0.66[c]	0.64[d]
C 6:0 Caproic acid	0.00[e]	0.32[a]	0.32[a]	0.30[b]	0.28[c]	0.25[d]
C 8:0 Caprylic acid	0.00[d]	0.19[a]	0.19[a]	0.17[b]	0.17[b]	0.15[c]
C 10:0 Capric (decanoic) acid	0.00[d]	0.26[a]	0.24[b]	0.24[b]	0.21[c]	0.21[c]
C 12:0 Lauric (dodecanoic) acid	0.00[d]	0.45[a]	0.44[a]	0.40[b]	0.39[b]	0.35[c]
C 14:0 Myristic (tetradecanoic) acid	0.00[d]	9.92[a]	9.43[b]	8.90[c]	8.40[d]	7.95[e]
C 16:0 Palmitic (hexadecanoic) acid	15.4[d]	26.80[a]	26.20[a]	25.69[b]	25.11[bc]	24.40[c]
C 18:0 Stearic (octadecanoic) acid	2.00[d]	14.00[a]	13.43[ab]	12.80[b]	12.21[bc]	11.72[c]
C 20:0 Arachidic (eicosanoic) acid	0.00[d]	1.00[a]	0.94[ab]	0.90[b]	0.84[bc]	0.79[c]
C 16:1 Palmitoleic (cis-9-hexadecenoic) acid	7.33[d]	13.22[a]	12.94[ab]	12.60[b]	12.30[bc]	12.14[c]
C 18:1 Oleic (cis-9-octadecenoic) acid	68.08[a]	27.10[d]	29.14[cd]	31.23[c]	33.29[b]	35.20[b]
C 18:2 Linoleic (9,12-octadecadienoic) acid	7.19[a]	4.90[d]	5.02[cd]	5.10[c]	5.25[bc]	5.46[b]
C 18:3 Linolenic (9,12,15-octadecatrienoic) acid	0.00[c]	1.05[a]	1.00[a]	0.98[ab]	0.88[b]	0.84[b]
The ratio of fatty acids						
SFA	17.40[e]	53.73[a]	51.91[b]	50.10[bc]	48.27[c]	46.47[d]
MUFA	75.41[a]	40.32[d]	42.08[c]	43.83[bc]	45.59[b]	47.34[b]
PUFA	7.19[a]	5.95[d]	6.01[cd]	6.08[c]	6.13[c]	6.20[b]
UFA	82.60[a]	46.27[d]	48.09[cd]	49.91[c]	51.72[bc]	53.54[b]
Health Lipid Indices						
AI	0.19[f]	1.45[a]	1.34[b]	1.24[c]	1.14[d]	1.06[e]
TI	0.42[e]	1.95[a]	1.83[b]	1.72[c]	1.62[d]	1.52[de]
DFA	84.60[a]	60.27[cd]	61.49[c]	62.71[bc]	63.92[b]	65.14b

AFPP Avocado fruit pulp powder, CMPC Camel's milk processed cheese, AI Atherogenic indices, TI Thrombogenic indices, DFA Hypocholesterolemic Fatty Acids, PUFA Polyunsaturated Fatty Acids, UFA Unsaturated fatty acids, MUFA Mono Unsaturated fatty acids, SFA Saturated fatty acids

3.5. Sensory Evaluation

Sensory features represent an essential variable factor in a consumer's decision to buy cheese; therefore, it is essential to ensure that additional substances have no an adverse effect on sensory attributes (50). Table 4 shows sensory evaluation findings for CMPC cheese samples enriched with different amounts of AFPP. Sensory characteristics of cheese samples were determined in freshly prepared samples. The results showed that there were no significant differences were observed regarding the flavor, body and texture, color and appearance, consistency and mouth feel among CMPC cheese samples fortified with (0, 5 and 10 % w/w) of AFPP. The scores of flavors, body and texture, color and appearance, consistency, and mouth feel were significantly lower in the CMPC fortified with AFPP (85:15 and 80:20 %w/w). The panelists reported that all processed cheese samples in this study were acceptable and received high overall acceptability scores ranged from 76.19 to 84.60. In this regard, Al-Hamdan et al., (51) discovered that fortifying fermented dairy products with dates significantly enhanced their sensory quality when compared to unfortified samples.

Table 4. Sensory evaluation of CMPC cheese enriched with different amounts of AFPP

Parameters	CMPC	Samples CMPC %+ AFPP % (w/w)			
		95:5	90:10	85:15	80:20
Flavor (30)	26.00^a±3.8	25.50^a±3.11	25.23^a±4.02	24.55^b±4.07	24.30^b±3.77
Body And Texture (30)	25.00^a±2.74	25.78^a±3.17	25.78^a±4.08	24.56^b±3.02	24.00^b±3.05
Color And Appearance (20)	17.00^a±1.87	16.23^a±2.14	16.21^a±2.33	15.00^b±1.03	14.53^c±2.08
Consistency (10)	8.00a±1.23	7.50a±1.18	7.50a±1.97	7.00b±2.45	6.36c±2.11
Mouth Feel (10)	8.00^a±1.08	7.79^a±1.05	7.70^a±1.14	7.40^b±1.18	7.00^c±1.06
Overall Acceptability (100)	84.00^a±2.16	82.80^a±2.13	82.42^a±2.70	78.51^b±2.35	76.19^c±2.42

Values are mean ± SD of 30 determinations.
Values with different superscript letters in the same row are significantly different ($p \leq 0.05$).

4. Conclusions

The incorporation of Avocado Fruit Pulp Powder (AFPP) into Camel Milk Processed Cheese (CMPC) significantly enhances its nutritional profile and sensory attributes. AFPP is rich in fat, protein, ash, and fiber, while CMPC primarily consists of moisture and protein. The addition of AFPP not only increases the fat, fiber, and mineral content of the cheese but also improves the fatty acid composition, reducing atherogenic and thrombogenic indices, which suggests health benefits associated with its consumption.

Acknowledgements

First and foremost, the author would like to thank Allah for giving us the strength and perseverance to complete this study.

Funding

The Researchers would like to thank the Deanship of Graduate Studies and Scientific Research at Qassim University for financial support (QU-APC-2025).

Institutional Review Board Statement

Not applicable.

Data Availability Statement

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

Conflicts of Interest

The authors declare no conflict of interest.

References

1. Weaver CM, Dwyer J, Fulgoni III VL, King JC, Leveille GA, MacDonald RS, et al. Processed foods: contributions to nutrition. Am J Clin Nutr. 2014;99(6):1525–42.

2. Jiménez-Colmenero F, Sánchez-Muniz FJ, Olmedilla-Alonso B. Design and development of meat-based functional foods with walnut: Technological, nutritional and health impact. Food Chem. 2010;123(4):959–67.
3. Ahmad S, Yaqoob M, Hashmi N, Ahmad S, Zaman MA, Tariq M. Economic importance of camel: Unique alternative under crisis. Pak Vet J. 2010;30(4):191–7.
4. Nori M, Kenyanjui MB, Yusuf MA, Mohammed FH. Milking drylands: The marketing of camel milk in north-east Somalia. Nomad People. 2006;10(1):9–28.
5. Musinga M, Kimenye D, Kivolonzi P. The camel milk industry in Kenya. Results of a study commissioned by SNV to explore the potential of Camel Milk from Isiolo District to access sustainable formal markets. 2008.
6. Kenya C. A report on the camel milk marketing clusters in Garissa. Vol. 20. 2009.
7. Fukuda K. Camel milk. Milk dairy Prod Hum Nutr Prod Compos Heal. 2013;578–93.
8. Salwa MQ, Lina AFK. Antigenotoxic and anticytotoxic effect of camel milk in mice treated with cisplatin. Saudi J Biol Sci. 2010;17(2):159–66.
9. Ereifej KI, Alu’datt MH, AlKhalidy HA, Alli I, Rababah T. Comparison and characterisation of fat and protein composition for camel milk from eight Jordanian locations. Food Chem. 2011;127(1):282–9.
10. Kamal M, Karoui R. Monitoring of mild heat treatment of camel milk by front-face fluorescence spectroscopy. LWT-Food Sci Technol. 2017;79:586–93.
11. Agrawal RP, Dogra R, Mohta N, Tiwari R, Singhal S, Sultania S. Beneficial effect of camel milk in diabetic nephropathy. Acta Biomed. 2009;80(2):131–4.
12. Mudgil P, Kamal H, Yuen GC, Maqsood S. Characterization and identification of novel antidiabetic and anti-obesity peptides from camel milk protein hydrolysates. Food Chem. 2018;259:46–54.
13. Zafar T, Sidhu JS. Avocado: production, quality, and major processed products. Handb Veg Veg Process. 2011;1871:525–43.
14. Lye HS, Ong MK, Teh LK, Chang CC, Wei LK. Avocado. In: Valorization of fruit processing by-products. Elsevier; 2020. p. 67–93.
15. Dreher ML, Davenport AJ. Hass avocado composition and potential health effects. Crit Rev Food Sci Nutr. 2013;53(7):738–50.
16. Duarte PF, Chaves MA, Borges CD, Mendonça CRB. Avocado: characteristics, health benefits and uses. Ciência Rural. 2016;46(4):747–54.
17. Nguyen TVL, Nguyen QD, Nguyen TTD, Nguyen PBD. Effects of infrared drying conditions and maltodextrin addition on some physicochemical characteristics of avocado (Persea americana) pulp powder. Appl Sci. 2021;11(24):11803.
18. Abbas KA, Abdelmontaleb HS, Hamdy SM, Aït-Kaddour A. Physicochemical, functional, fatty acids profile, health lipid indices, microstructure and sensory characteristics of walnut-processed cheeses. Foods. 2021;10(10):2274.
19. Guinee TP. Pasteurized processed and imitation cheese products. In: Cheese. Elsevier; 2017. p. 1133–84.
20. Sołowiej BG, Nastaj M, Szafrańska JO, Muszyński S, Gustaw W, Tomczyńska-Mleko M, et al. Effect of emulsifying salts replacement with polymerised whey protein isolate on textural, rheological and melting properties of acid casein model processed cheeses. Int Dairy J. 2020;105:104694.
21. Rafiq SM, Ghosh BC. Effect of peanut addition on the fatty acid profile and rheological properties of processed cheese. Food Process. 2017;8(2).

22. Solhi P, Azadmard-Damirchi S, Hesari J, Hamishehkar H. Production of the processed cheese containing tomato powder and evaluation of its rheological, chemical and sensory characteristics. J Food Sci Technol. 2020;57:2198–205.
23. El-Metwally RI, El-Menawy RK, Ismail MM. Correlation between free fatty acids content and textural properties of Gouda cheese supplemented with denatured whey protein paste. J Food Sci Technol. 2023;60(2):590–9.
24. AOAC. Official Methods of Analysis. Association of Officials. Analytical Chemist. Washington: Benjamin Franklin Station; 2005.
25. Ling ER. Textbook of dairy chemistry. London: Chapman & Hall; 1963.
26. El-Anany AM, Ali RFM, Elanany AMM. Nutritional and quality characteristics of chicken nuggets incorporated with different levels of frozen white cauliflower. Ital J Food Sci. 2020;32(1).
27. Althwab SA, Alhomaid RM, Ali RFM, Mohammed El-Anany A, Mousa HM. Effect of migratory locust (Locusta migratoria) powder incorporation on nutritional and sensorial properties of wheat flour bread. Br Food J. 2021;123(11):3576–91.
28. ISO 15884:2024. International Organization for Standardization ISO. 2002 [cited 2003 Jul 12]. Milk fat-Preparation of fatty acid methyl esters. Available from: https://www.iso.org/obp/ui/#iso:std:iso:15884:ed-1:v1:en
29. Ulbricht TL V, Southgate DAT. Coronary heart disease: seven dietary factors. Lancet. 1991;338(8773):985–92.
30. Ali RFM, Althwab SA, Alfheeaid HA, El-Anany AM, Alhomaid RM, Alharbi HF. Nutritional and quality characteristics of wheat bread fortified with different levels of soaked–dehulled moth bean (Vigna aconitifolia) seeds powder. Br Food J. 2022;124(5):1537–50.
31. Castañeda-Saucedo MC, Valdés-Miramontes EH, Tapia-Campos E, Delgado-Alvarado A, Bernardino-García AC, Rodríguez-Ramírez MR, et al. Effect of freeze-drying and production process on the chemical composition and fatty acids profile of avocado pulp. Rev Chil Nutr. 2014;41(4):404–11.
32. USDA (United States Department of Agriculture). Avocado Composition. Washington DC: Department of Agriculture Washington, DC; 2011.
33. Bachmann HP. Cheese analogues: a review. Int dairy J. 2001;11(4–7):505–15.
34. Mehanna NS, Hassan FAM, El-Messery TM, Mohamed AG. Production of functional processed cheese by using tomato juice. Int J Dairy Sci. 2017;12:155–60.
35. Mooz ED, Gaiano NM, Shimano MYH, Amancio RD, Spoto MHF. Physical and chemical characterization of the pulp of different varieties of avocado targeting oil extraction potential. Food Sci Technol. 2012;32:274–80.
36. Othman NA, Abdul Manaf M, Harith S, Wan Ishak WR. Influence of avocado puree as a fat replacer on nutritional, fatty acid, and organoleptic properties of low-fat muffins. J Am Coll Nutr. 2018;37(7):583–8.
37. Mohamed AG, El-Salam B, Gafour WAE. Quality Characteristics of Processed Cheese Fortified with Spirulina Powder. Pak J Biol Sci. 2020;23(4):533–41.
38. Yadav S, Mishra S. Optimization and Standardization of Spreadable Cheese Fortified with Mushroom Powder. Acta Sci Nutr Heal. 2022;6(7):67–72.
39. Engberink MF, Hendriksen MAH, Schouten EG, van Rooij FJA, Hofman A, Witteman JCM, et al. Inverse association between dairy intake and hypertension: the Rotterdam Study. Am J Clin Nutr. 2009;89(6):1877–83.
40. Assies J, Lok A, Bockting CL, Weverling GJ, Lieverse R, Visser I, et al. Fatty acids and

homocysteine levels in patients with recurrent depression: an explorative pilot study. Prostaglandins, Leukot Essent Fat acids. 2004;70(4):349–56.

41. Flores M, Saravia C, Vergara CE, Avila F, Valdés H, Ortiz-Viedma J. Avocado oil: Characteristics, properties, and applications. Molecules. 2019;24(11):2172.
42. Krauss RM, Eckel RH, Howard B, Appel LJ, Daniels SR, Deckelbaum RJ, et al. AHA Dietary Guidelines: revision 2000: A statement for healthcare professionals from the Nutrition Committee of the American Heart Association. Circulation. 2000;102(18):2284–99.
43. Wylie-Rosett J. Fat substitutes and health: an advisory from the Nutrition Committee of the American Heart Association. Circulation. 2002;105(23):2800–4.
44. Attia YA, Al-Harthi MA, Korish MA, Shiboob MM. Fatty acid and cholesterol profiles, hypocholesterolemic, atherogenic, and thrombogenic indices of broiler meat in the retail market. Lipids Health Dis. 2017;16:1–11.
45. Williams CM. Dietary fatty acids and human health. In: Annales de zootechnie. EDP Sciences; 2000. p. 165–80.
46. Paszczyk B, Łuczyńska J. Fatty acids profile, conjugated linoleic acid contents and fat quality in selected dairy products available on the Polish market. Czech J Food Sci. 2020;38(2).
47. Osmari EK, Cecato U, Macedo FAF, Souza NE. Nutritional quality indices of milk fat from goats on diets supplemented with different roughages. Small Rumin Res. 2011;98(1–3):128–32.
48. Babatola LJ, Adebayo A, Ifijeh J, Oboh G. Effect of avocado seed extract on lipid profile and atherogenic index in cyclosporine-treated rats. J Curr Biomed Res. 2023;3(1, January-February):726–40.
49. Khalili Tilami S, Kouřimská L. Assessment of the nutritional quality of plant lipids using atherogenicity and thrombogenicity indices. Nutrients. 2022;14(18):3795.
50. Kondyli E, Pappa EC, Arapoglou D, Metafa M, Eliopoulos C, Israilides C. Effect of fortification with mushroom polysaccharide β-glucan on the quality of ovine soft spreadable cheese. Foods. 2022;11(3):417.
51. Alhamdan AM, Al Juhaimi FY, Hassan BH, Ehmed KA, Mohamed Ahmed IA. Physicochemical, microbiological, and sensorial quality attributes of a fermented milk drink (Laban) fortified with date syrup (dibs) during cold storage. Foods. 2021;10(12):3157.