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Research Article
Effect of Quinoa (*Chenopodium quinoa*) Flour on the Production and Quality of Low-Fat Camel Milk Processed Cheese Spread

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Abstract
Background and Objective: Camel milk has nutritional and therapeutic properties. Quinoa flour has been incorporated into many kinds of food because of its various nutrients and bio-actives. This study aimed to investigate the effect of using quinoa flour on the properties of low-fat camel milk processed cheese spread (LF-CMPCS) made from fermented retentate camel milk as a camel cheese base. **Materials and Methods:** Quinoa flour was used to substitute 1, 3 and 5% of the camel cheese base made with Ras cheese. The resultant cheeses were analyzed for several parameters. Such as physiochemical, texture properties, antioxidant activity, fatty acids, microstructure and organoleptic properties as fresh and during storage period at 5±1°C for 3 months. The data were analyzed by ANOVA using the SPSS computer program. **Results:** Total solids, protein, fat/dry matter and soluble nitrogen decreased significantly while the fiber, carbohydrates and pH values increased significantly. Meltability value of LF-CMPCS significantly decreased. The results indicated that the hardness increased significantly with the increase in the addition of quinoa flour. The fatty acid profile indicated a significant increase in oleic acid (18:1), linoleic acid (18:2), linolenic (18:3) and eicosenoic (20:1) with the increase of quinoa flour. Scanning electron microscopy (SEM) images showed the presence of quinoa flour in the space within the casein particle network. **Conclusion:** It could be concluded that the addition of quinoa flour to camel cheese (up to 3%) can improve the chemical, sensory and microstructure and texture properties of LF CMPCS camel milk cheese without altering the quality of the product.

Key words: Camel milk, cheese base, cheese microstructure, cheese color, meltability, fatty acid, texture profile, quinoa flour

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Camel milk has a significant role in human nutrition. It has been used in different regions around the world and it could become one of the new super foods. Recently, camel milk has potential therapeutic properties, such as anti-carcinogenic, anti-diabetic and antihypertensive[1]. Regarding to camel milk health benefits, it has been recommended for children who are allergic to bovine milk and suitable for people with lactose in tolerance. Camel milk is very rich in minerals and vitamins and it can be used in several healthy products such as fermented milk, butter and cheese[2,3].

Processed cheese represents an extremely delicate and complex system as its properties are influenced by many factors, such as the composition and character of the base cheeses used as ingredients, type and amount of melting, salts, pH and processing parameters[4]. The processed cheese model reduced the degree of melting due to cooking. Both firmness and degree of melt of the processed cheese upon heating were related to the amylose content of the starches used. This decrease in the extent of melt could have prospective benefits in terms of product stability during heating and cooking[5].

Young cheese was used to provide the texture and the strength to the processed cheese, whereas mature (Aged) cheese provides a cheesy and cheddar-like flavor. In cheese production, cheese, butter and protein powders are considered the costliest ingredients because of the industrial desire to reduce the cost of processed cheese formulations. A great effort is made to reduce the protein content and to increase the moisture content instead, to reduce the high cost of caseins (proteins) and avoid certain functionality restrictions[6,7]. Abdeen *et al*.[8] reported that the cheese base from camel milk retentate could successfully replace the Ras cheese in low fat, processed cheese spread production with different addition levels up to 50% without altering the cheese quality.

Quinoa (*Chenopodium quinoa*) is a pseudo cereal that is considered as healthy as a grain with high nutritional value, these grains are gluten-free. Quinoa flour contains high protein content and its protein presents adequate levels of essential amino acids. It has a hypoglycemic effect and is a good regulator for blood glucose and cholesterol. Quinoa flour has higher levels of important minerals such as potassium, calcium, magnesium, phosphorus, sulfur, iron and zinc. It also contains some vitamins such as riboflavin and those of group B[9,10]. Also, it contains dietary fiber and is rich in unsaturated Fatty acid, mainly consisting of linoleic (52%) and oleic acids (25%). Quinoa flour contains bioactive compounds such as flavonoids and phenolic acids that have antioxidant activities, prospective health benefits and biological properties[11,12]. Starch in quinoa flour ranged from 48-69% of the whole kernel. Starch from various quinoa varieties shows differences in amylose content, granular structure and size as well as the molecular structure of amylopectin and amylose. These differences perhaps affected in physiochemical properties such as swelling, solubility, pasting, gelatinization and retrogradation[13,14]. The starches are used for improving the rheological properties of processed cheese, reducing production costs, ensuring the consistency of the products, extending shelf life and health benefits. The addition of starch to a classical processed cheese spread increases the firmness of the produced cheese. The level of this increase strongly depends on the amount and the type of the starch added. A decrease in the protein level resulted in a reduction in firmness. The starch supplement could redeem this. Starch is inexpensive compared to milk protein, therefore, starch can be added to partially substitute the young cheese that is used mainly as a protein source in processed cheese formulations without affecting the firmness of the manufacture processed cheese[15,16]. The objective of this work was to study the effect of using different concentrations of quinoa flour on the production and quality of low-fat processed cheese spread that manufactured from fermented camel milk retentate (as a camel cheese base). This study included several measurements, such as the physicochemical, antioxidant activity, fatty acids profile, microstructure, textural profile. Also, the organoleptic properties of the final product during storage periods of three months at refrigerator temperature 5±1°C.

MATERIALS AND METHODS

Study area: The study was carried out from September, 2018 to April, 2019. All tests were done in Animal Breeding Department, Animal and Poultry Production Division, Desert Research Centre, Matariya, Cairo, Egypt and Dairy Science Department, Faculty of Agriculture, Zagazig University, Egypt.

Milk source: Raw camel milk [total solid (TS) 11.69%, protein 2.81%, fat 3.4%, lactose 4.41%, ash 0.81 and pH 6.69] was obtained from Matrouh Station of Desert Research Center, Ministry of Agriculture, Cairo, Egypt. Camel milk retentate and permeate were filtrated using the ultra filtration system with a carbo-sep laboratory unit (SFEC, France) equipped with 0.7 m^2 inorganic zirconium oxide membrane (molecular cut off 50,000). Rennet Hannilase@ TL 2300 granulate NB microbial rennet and freeze-dried starter cultures containing:

Streptococcus thermophilus and *Lactobacillus Delbrueckii* ssp. *bulgaricus* were obtained from Christian. Hansen's Lab., Copenhagen, Denmark by Misr Food Additives (MIFAD), Egypt. Commercial emulsifying salts S9 (E452 sodium polyphosphate, E339 sodium orthophosphate) were obtained from Joha company, BK-Ladenburg corp, GmbH, Germany. It was obtained from the local market. White Chenopodium quinoa grains, procured from Desert Research Center (DRC) Egypt. Ras cheese, young (1 month) and aged (3 months) was made by the method of Hofi *et al.*[17] at the Department of Food Science, Faculty of Agriculture, Zagazig University, Egypt. Quinoa flour was prepared using the methods described by El Sohaimy *et al.*[18] with some modifications steps that involved washing to remove saponins contents. After seeds were dried and grinded to become quinoa flour powder, it was kept at 5°C for further analysis. Chemical composition of raw materials used in the production of low-fat processed cheese spread presented in Table 1.

Camel cheese base production: Raw camel milk was used in cheese base production as described by Abdeen *et al.*[8] and the results, called camel cheese base.

Manufacture of low-fat processed cheese spread: Standard and four different formulas of LF-CMPCS containing 0, 1, 3 and 5% quinoa flour were presented in Table 2. Control (Young+aged Ras cheese), T1: Aged Ras cheese+camel cheese base (70%), T2: Aged Ras cheese+camel cheese base (70%)+1% quinoa flour, T3: Aged Ras cheese+camel cheese base (61.5%)+3% quinoa flour and T4: Aged Ras cheese+camel cheese base (48.2%)+5% quinoa flour were prepared. Other ingredients were added to all formulas permeate and emulsifying salts S9. The emulsifying salts S9 (3% was added to control and T1 while 1% was added to other treatments T2, T4 and T5). Details information about the cooking machine was described previously by Meyer[19]. The ingredients were mixed for about 1 min. Then the mixture was cooked for 10 min at 80-85°C using indirect steam process at pressure 1.5-2.0 kg cm^{-2}. The melted low-fat cheese spread samples were transferred to glass jars and sealed then stored at refrigerator temperature 5±1°C for 3 months. Three replicates were made from each treatment and analyzed in duplicated samples.

Chemical analysis: Moisture, acidity, fiber and ash contents were determined in LF-CMPCS samples according to the standard methods in AOAC[20]. Fat and total soluble nitrogen contents were determined according to Ling[21]. pH values were measured using a digital pH meter (HANNA Digital Instruments pH meter Hi, 8014 Italy). Total carbohydrates were measured as described by James[22].

Table 1: General chemical composition (%) means±SD of the raw materials used in producing LF-CMPCS supplemented with quinoa flour

	General chemical composition (%)				
Parameters	Young Ras cheese	Aged Ras cheese	Cheese base	Permeate	Quinoa flour
Dry matter	61.73±18.74[b]	63.45±20.89[b]	22.12±1.13[c]	8.40±1.17[c]	94.50±174[a]
Fat	27.10±8.87[a]	28.30±12.05[a]	8.50±0.85[b]	0.50±0.09[c]	6.30±0.60[b]
Protein	24.90±8.80[a]	25.30±7.86[a]	7.30±0.95[bc]	1.60±0.70[c]	16.30±1.72[ab]
Salt	3.09±0.20[b]	3.60±0.39[a]	25.30±7.86[a]	ND	ND
Ash	3.85±0.44[a]	4.19±0.21[a]	0.70±0.26[b]	0.58±0.70[b]	3.80±0.23[a]
Carbohydrate	ND	ND	ND	ND	66.50±2.25[a]
Lactose	2.28±0.15[c]	1.39±0.06[d]	3.80±0.39[b]	5.30±0.32[a]	ND
Total dietary fiber	-	-	-	-	2.70±0.34[a]

ND: Not detected, [a-d]Means within a row with different superscripts differ ($p \leq 0.05$)

Table 2: Formulation of low-fat camel milk processed cheese spread supplemented with quinoa flour

	Treatments				
Ingredients (kg)	C	T1	T2	T3	T4
Young Ras cheese	12.40	0.00	0.00	0.00	0.00
Aged Ras cheese	24.60	20.90	20.90	20.90	20.90
Camel cheese base	0.00	70.00	70.00	61.50	48.20
Quinoa flour	0.00	0.00	1.00	3.00	5.00
Emulsifying salt S9	3.00	3.00	1.00	1.00	1.00
Permeate	60.00	6.10	7.10	13.60	24.90
Total	100.00	100.00	100.00	100.00	100.00

Control (C): Young and aged Ras cheese, T1: Aged Ras cheese+Camel cheese base (70%), T2: Aged Ras cheese+Camel cheese base (70%)+1% quinoa flour, T3: Aged Ras cheese+Camel cheese base (61.5%)+3% quinoa flour, T4: Aged Ras cheese+Camel cheese base (48.2%)+5% quinoa flour

Meltability of cheese samples was determined by the method of Fernandez and Kosikowski[23] using Digital Planimeter (PLACOM, KP-90N Digital Planimeter, Koizumi Placom, Japan). The percentage of Meltability was calculated from the following equation:

$$\text{Meltability (\%)} = \text{Area of melted discs-Area of original discs}$$

Color analysis: Cheese color was measured using a Mini Scan portable colorimeter (Hunter Associates Laboratory Inc., Reston, VA, USA). Color standardization was done using black and white standard plates placed in a 3.5 mL plastic bag normally used for cheese packaging. The measurements for cheese color were done by using commission International de l'Eclairage[24] L*, a* and b* values with illuminant D65. The a* value is an indicator of red (+) and green (–). The b*value is an indicator of yellow (+) and blue (–). The L*value is an indicator of luminosity (the degree of lightness from black to white). Because combining a* value and b*value gives a better color indication than their individual values, hue angle was calculated as the inverse tangent of the ratio b*/a* according to the manufacturer's instructions. The petri dish was placed directly on the colorimeter sensor. The color intensity (C*) "Eq. 1", the hue angle ($h_{ab}°$) "Eq. 2" and total color difference (ΔE) "Eq. 3" in comparison to the untreated control, was calculated as, whereas $h_{ab}° = 90°$ for a yellow hue and $h_{ab}° = 0°$ for a red hue, the values were expressed as follow:

$$\text{Color intensity } (C^*) = (a^{*2}+b^{*2})^{0.5} \quad (1)$$

$$\text{Hue angle } (h_{ab}°) = \text{Arctan } (b^*/a^*) \quad (2)$$

$$\text{Total color difference } (\Delta E) = [(L-L0)^2+(a-a0)^2+(b-b0)^2]^{0.5} \quad (3)$$

The color was expressed as a whiteness index (WI*) Eq. 4 based on the following formula[25]:

$$WI^* = 100-[(100-L^*)^2+a^{*2}+b^{*2}]^{0.5} \quad (4)$$

The Browning Index (BI*) Eq. 5 was calculated as described by Palou *et al.*[26] using the following formula:

$$\text{Browning index } (BI^*) = [100(x-0.31)]/0.172 \quad (5)$$

Where:

$$x = [(a + 1.75L)/ (5.645L + (a - 3.012b))]$$

Texture profile analysis (TPA): Texture measurements of samples were performed according to Bourne[27] with the universal testing machine (Cometech, B type, Taiwan) provided with the software. Back extrusion cell with a 35 mm diameter compression disc.

Determination of antioxidant activity and total phenolic contents (TPC): For antioxidant activity, LF-CMPCS samples were extracted according to the protocol described by Shaiban *et al.*[28] with some modifications. About 2 g of the cheese sample was homogenized and extracted with 20 mL of 80% methanol containing 1% HCl for 30 min. Each sample was re-extracted three times. The mixture was then centrifuged for 15 min at 5000 rpm. The supernatant was collected and stored at 2°C for further analysis to evaluate the antioxidant activity. The concentration of total phenolic in low-fat camel milk processed cheese spread samples was determined by Folin-Ciocalteus procedure[29] and expressed as mg g^{-1} of cheese as catechins equivalent (CE). Cheese extract (0.3 mL) was mixed with 0.2 N Folin-Ciocalteu's reagent (1.5 mL). After 5 min, 1.2 mL of 0.7 N Na_2CO_3 solution were added. The mixture was incubated for 2 h at room temperature. The absorbance of the reaction was measured at 765 nm, using a UV-VIS-1200A spectrophotometer (Dayton, USA) against a blank sample as reference.

Determination of antioxidant activity: The antioxidant activity was determined by the ability of the antioxidants to scavenging activity of DPPH (1,1-diphenyl-2-picrylhydrazyl) as described by Brand-Williams *et al.*[30] which was modified by Re *et al.*[31]. The experiments were conducted in triplicate and the mean values were used. The antioxidant activity was calculated using the following equation:

$$\text{Scavenging activity (\%)} = \frac{Abs_{control} - Abs_{sample}}{Abs_{control}} \times 100$$

Minerals determination: Minerals were determined in the ash solution[32]. Calcium, magnesium, phosphorus, manganese, copper, iron and zinc concentrations were determined using an atomic absorption spectrophotometer (Unicam Analytical System, Model 919, Cambridge, UK) while sodium and potassium concentrations were determined using flame photometer (Jenway PF7 Flame Photometer, Essex, UK).

Scanning electron microscopy: LF-CMPCS samples were examined using SEM (FEI company, Netherlands) Model Quanta 250 FEG (Field Emission Gun) attached with EDX Unit (Energy Dispersive X-ray Analyses), with accelerating voltage 10 K.V. Samples were freeze-fractured in liquid nitrogen to approximately 1 mm pieces and these pieces were then mounted on aluminum stubs and scanned under low vacuum condition with pressure champers of 60 Pas. Images were taken at 1000×magnification according to the setup described by Karami *et al.*[33].

Fatty acids analysis: Fatty acids were extracted as descended by AOAC[20] at National Food Institution and transferred to methyl esters. The methyl-esters were prepared by a weight of 10 mg sample in a 2 mL test tube (with a screw cap). Dissolve the sample in 1 mL of hexane then add 10 mL of 2 N hydroxide in methanol (11.2 g in 100 mL). After that close the tube and vortex for 30 sec. Samples were analyzed using gas chromatography Ultra trace GC DSQ (Thermo Fisher Scientific, Austin, USA). The mass detector was used. And the results were expressed as a percent of the relative area as described by Dabbou *et al.*[34].

Organoleptic properties: Samples of LF-CMPCS were sensory scored by 8-10 panelists according to the scheme of Meyer[19] for external appearance (20 points). Body and texture was counted for 40 points and aroma and flavor (40 points). The course of scoring for each sample was repeated three times and all collected data were statistically analyzed using the SPSS software (SPSS Inc., Chicago, IL, USA) using the liner Model (GLM). Duncan's multiple range was used to separate among means of 3 replicates at $p \leq 0.05$.

Statistical analysis: The data were analyzed by ANOVA according to the appropriate experimental designs and reported as means±standard deviations, which were separated by Duncan's new multiple range test at $p \leq 0.05$ and least significant difference (LSD) test using SPSS computer program, version 16.0 (SPSS Inc.). All analysis and measurements were repeated in triplicates.

RESULTS AND DISCUSSION

Chemical composition of low-fat camel milk processed cheese spread (LF-CMPCS): The chemical composition of low-fat camel milk processed cheese spread (LF-CMPCS) supplemented with 1, 3 and 5% quinoa flour are presented in Table 3. The results can be compared with the data from previous studies Awad[35] and El-Dardiry *et al.*[36]. The data in Table 3 show that LF- CMPCS supplemented with quinoa flour has narrow range of differences in moisture, fat/DM contents for T2, T3 and T4 treatments compared to the control and T1. Moreover, the results for fat content show no significant differences ($p \leq 0.05$) in all treatments compared to the control and T1. These results were similar to the results obtained by Awad[35] and El-Dardiry *et al.*[36]. The results also confirmed that protein content change in a very narrow range with no significant ($p \leq 0.05$) change. With regards to ash percentage, the data in Table 3 show that ash content decreased significantly ($p \leq 0.05$) as the added level of quinoa increased. These results agree with El-Dardiry *et al.*[36]. Total solid content increased significantly ($p \leq 0.05$) for T2, T3, T4 with the increase of quinoa flour ratio compared to the control and T1. The results for fat content and the total solids of the low-fat processed cheese spread agreed with the values for the Egyptian standards LF-CMPCS. Overall, Carbohydrate and dietary fiber contents were the highest in treatments with quinoa flour (T2, T3 and T4) and the lowest in control and T1 (without quinoa flour). These results may be due to the decrease in the percentage of cheese base and aged Ras cheese added with increasing the percentage of quinoa flour. This conclusion is based on the higher contents of these components in quinoa flour used in fortification of low-fat processed cheese spread compared to Ras cheese used in base formula as presented in Table 1. These results and interpretation agree with the results reported by

Table 3: Chemical composition (%) of fresh low-fat camel milk processed cheese spread supplemented with quinoa flour

	Treatments				
Properties (%)	C	T1	T2	T3	T4
Moisture	60.09 ± 0.33^{ab}	59.04 ± 0.54^{ab}	59.91 ± 0.34^{a}	58.23 ± 1.78^{ab}	57.16 ± 2.16^{b}
Total solid	39.94 ± 0.35^{e}	40.09 ± 0.32^{d}	40.96 ± 0.50^{c}	41.77 ± 0.50^{b}	42.84 ± 0.50^{a}
Fat	9.80 ± 1.24^{a}	10.10 ± 1.05^{a}	10.10 ± 1.79^{a}	9.60 ± 1.85^{a}	8.80 ± 1.38^{a}
Fat/DM	24.56 ± 2.28^{ab}	24.66 ± 0.79^{ab}	25.19 ± 1.03^{a}	22.98 ± 1.20^{b}	20.45 ± 0.93^{c}
Protein	10.31 ± 1.25^{a}	11.24 ± 0.26^{a}	11.40 ± 0.71^{a}	11.01 ± 0.33^{a}	10.62 ± 1.51^{a}
Carbohydrate	3.80 ± 0.22^{bc}	3.27 ± 0.26^{c}	4.25 ± 0.07^{bc}	5.13 ± 0.90^{b}	7.16 ± 0.93^{a}
Ash	5.17 ± 0.86^{a}	4.56 ± 0.65^{a}	2.85 ± 0.40^{b}	2.91 ± 0.37^{b}	2.95 ± 0.33^{b}
Dietary fiber	-	-	0.26 ± 0.05^{c}	0.79 ± 0.06^{b}	1.39 ± 0.04^{a}

[a-c]Means within a row with different superscripts differ ($p \leq 0.05$), Control (C): Young and aged Ras cheese, T1: Aged Ras cheese+Camel cheese base (70%), T2: Aged Ras cheese+Camel cheese base (70%), +1% quinoa flour, T3: Aged Ras cheese+camel cheese base (61.5%)+3% quinoa flour, T4: Aged Ras cheese+Camel cheese base (48.2%)+5% quinoa flour

Table 4: pH values mean±SD of low-fat camel milk processed cheese during storage period at 5±1°C

Storage period (months)	Treatments C	T1	T2	T3	T4	Total means
Fresh	5.63±0.37[a]	5.66±0.40[a]	5.68±0.51[a]	5.72±0.46[a]	5.74±0.48[a]	5.68±0.38[A]
1	5.59±0.23[a]	5.62±0.30[a]	5.63±0.49[a]	5.67±0.38[a]	6.71±1.06[a]	5.84±0.66[A]
2	5.50±0.48[a]	5.53±0.25[a]	5.57±0.12[a]	5.60±0.55[a]	6.12±0.19[a]	5.66±0.39[A]
3	5.46±1.41[a]	5.49±1.24[a]	5.55±1.28[a]	5.56±1.17[a]	5.58±1.33[a]	5.52±1.09[A]
Total means	5.54±0.57[A]	5.57±0.58[A]	5.61±0.63[A]	5.64±0.61[A]	6.04±0.88[A]	5.65±0.68

[a]Means within a row with different superscripts and means with different superscript at the last column differ ($p \leq 0.05$), Control (C): Young and aged Ras cheese, T1: Aged Ras cheese+Camel cheese base (70%), T2: Aged Ras cheese+Camel cheese base (70%)+1% quinoa flour, T3: Aged Ras cheese+Camel cheese base (61.5%)+3% quinoa flour, T4: Aged Ras cheese+Camel cheese base (48.2%)+5% quinoa flour

El-Dardiry *et al*.[36]. In general, most of the results for the chemical composition of low-fat camel milk processed cheese spread (LF-CMPCS) supplemented with 1, 3 and 5% quinoa flour were supported by El-Dardiry *et al*.[36].

pH values: Results from Table 4 show the changes in pH values while Fig. 1a shows the changes in soluble nitrogen (SN) of LF-CMPCS supplemented with different ratios of quinoa flour. The pH values of fresh LF-CMPCS supplemented with quinoa flour recorded the highest values with the increase of the quinoa flour ratio. While the control sample and T1 recorded the lowest values. The pH values of all treatments decreased at the end of the storage period. These results agreed with Awad[35] and El-Dardiry *et al*.[36].

Meltability and soluble nitrogen (SN): Results from Fig. 1a show the effect of supplementation of quinoa flour by different ratios on meltability value (ability to soften) of LF-CMPCS supplemented with quinoa flour. The meltability of fresh LF-CMPCS decreased ($p \leq 0.05$) significantly with the increase of the quinoa flour ratio. The lowest value was for T2 compared to the control sample. The meltability of all storage cheeses was also decreased ($p \leq 0.05$) significantly during the storage period. This result could be related to the low protein degradation. The data agree with those of Mounsey and O'Riordan[37]. On the other hand, Fig. 1b showed the changes in soluble nitrogen (SN) of LF-CMPCS supplemented with different ratio of quinoa flour. The SN content of fresh LF-CMPCS supplemented with quinoa flour decreased ($p \leq 0.05$) significantly with the increase of quinoa flour ratio. Also, the SN content of all treatments increased ($p \leq 0.05$) significantly during storage period. Among all treatments, the fresh LF-CMPCS had the lowest soluble nitrogen content which can be attributed to low quantity of Ras cheese used and cheese base had low content of SN. During storage, the SN slowly increased after three months, which may be due to the enzymatic activity of resistant proteinases. Similar results were reported by Awad35 and El- Dardiry *et al*.[36].

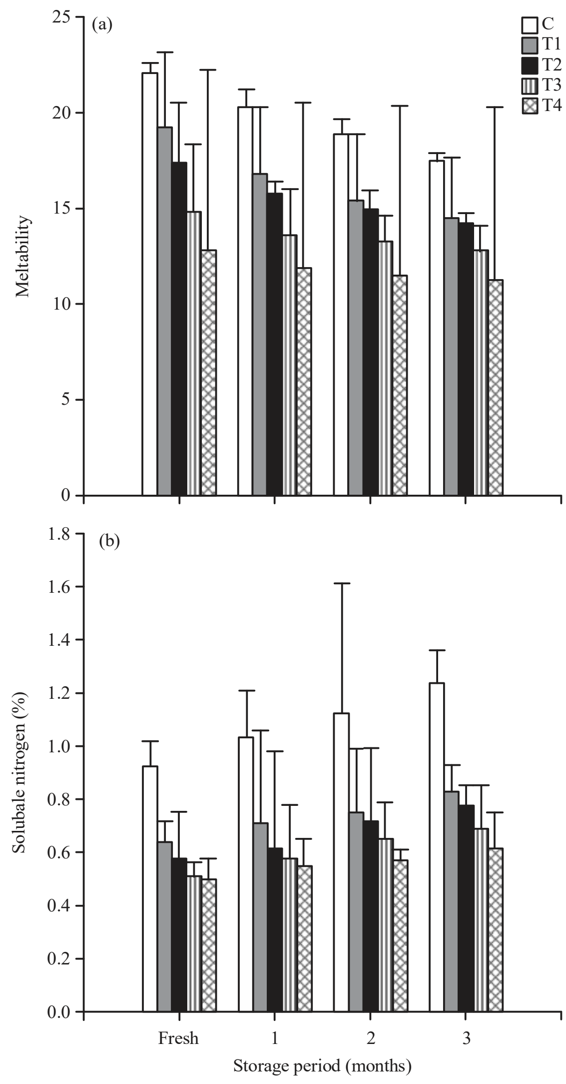

Fig. 1(a-b): (a) Meltability and (b) Soluble nitrogen of LF-CMPCS during storage period at 5±1°C
Treatments: Control (C): Young and aged Ras cheese, T1: Aged Ras cheese+Camel cheese base (70%), T2: Aged Ras cheese+Camel cheese base (70%)+1% quinoa flour, T3: Aged Ras cheese+Camel cheese base (61.5%)+3% quinoa flour, T4: Aged Ras cheese+Camel cheese base (48.2%)+5% quinoa flour

Textural profile analysis (TPA): Data from Table 5 illustrated the textural parameters of LF-CMPCS supplemented with quinoa flour. It is noticed that the hardness increased ($p \leq 0.05$) significantly with the increase of the quinoa flour ratio. The hardness recorded the highest values in T2, T3 and T4, respectively. Also, the hardness values of all treatments increased ($p \leq 0.05$) significantly during the storage period for 3 months. Other texture parameters, such as adhesiveness, cohesiveness, gumminess, springiness and chewiness, were determined. All treatments showed significantly ($p \leq 0.05$) low values with the increase of quinoa flour ratio supplementation compared with the control. The adhesiveness, cohesiveness and springiness values were recorded in Table 5. Gumminess values decreased with the increase of quinoa flour ratio. Chewiness value was the highest in T2 treatment. During the storage period, all texture parameters increased significantly ($p \leq 0.05$) in all treatments except for adhesiveness and springiness that were not significant. These results are in agreement with Trivedi *et al.*[16] and Awad *et al.*[38].

Color analysis of low-fat camel milk processed cheese spread: Color changes of LF-CMPCS supplemented with different ratios of quinoa flour during the storage period of three months are shown in Table 6. Luminosity (L*) values of fresh LF-CMPCS supplemented with quinoa flour recorded the lowest values with the increase in the quinoa ratio compared with the values for control. The same trend was observed

Table 5: Texture profile analysis (TPA) means±SD of LF-CMPCS during storage period at 5±1°C

Parameters	Storage period (months)	Treatments C	T1	T2	T3	T4	Total means
Hardness (N)							
	Fresh	2.80 ± 0.20^{bc}	1.93 ± 0.08^{c}	2.35 ± 0.11^{c}	3.45 ± 0.34^{b}	5.16 ± 0.65^{a}	3.14 ± 1.21^{D}
	1	3.20 ± 0.31^{b}	2.35 ± 0.11^{c}	3.75 ± 0.24^{b}	3.95 ± 0.33^{b}	6.21 ± 0.32^{a}	3.88 ± 1.33^{C}
	2	5.20 ± 0.31^{c}	3.63 ± 0.22^{d}	6.65 ± 0.40^{b}	5.75 ± 0.34^{bc}	9.56 ± 0.54^{a}	6.16 ± 2.06^{B}
	3	8.20 ± 0.66^{bc}	6.63 ± 1.15^{c}	10.65 ± 1.14^{b}	9.75 ± 1.20^{b}	13.76 ± 1.38^{a}	9.79 ± 2.67^{A}
	Total means	4.85 ± 2.25^{C}	3.64 ± 1.99^{D}	5.85 ± 3.36^{B}	5.73 ± 2.65^{B}	8.66 ± 3.59^{A}	5.74 ± 3.21
Adhesiveness (mj)							
	Fresh	5.63 ± 0.39^{a}	2.64 ± 0.28^{b}	4.62 ± 0.40^{a}	4.37 ± 0.52^{a}	4.75 ± 0.77^{a}	4.40 ± 1.09^{A}
	1	5.65 ± 0.62^{a}	2.65 ± 0.23^{b}	4.64 ± 0.69^{a}	4.40 ± 0.42^{a}	4.77 ± 0.50^{a}	4.42 ± 1.11^{A}
	2	5.68 ± 0.42^{a}	2.68 ± 0.27^{c}	4.65 ± 0.60^{ab}	4.41 ± 0.17^{b}	4.80 ± 0.55^{ab}	4.44 ± 1.07^{A}
	3	5.75 ± 0.52^{a}	2.69 ± 0.34^{c}	4.68 ± 0.56^{ab}	4.45 ± 0.20^{b}	4.84 ± 0.55^{ab}	4.48 ± 1.03^{A}
	Total means	5.67 ± 0.39^{A}	2.67 ± 0.24^{C}	4.65 ± 0.49^{B}	4.41 ± 0.31^{B}	4.79 ± 0.51^{B}	4.43 ± 1.07
Cohesiveness (Ratio)							
	Fresh	0.99 ± 0.99^{a}	0.91 ± 0.07^{ab}	0.70 ± 0.10^{bc}	0.57 ± 0.13^{c}	0.81 ± 0.01^{ab}	0.79 ± 0.17^{B}
	1	1.00 ± 0.09^{a}	0.93 ± 0.08^{a}	0.71 ± 0.07^{bc}	0.58 ± 0.07^{c}	0.83 ± 0.01^{ab}	0.81 ± 0.17^{B}
	2	1.02 ± 0.09^{ab}	0.96 ± 0.04^{abc}	1.25 ± 0.23^{a}	0.62 ± 0.12^{c}	0.86 ± 0.06^{bc}	0.94 ± 0.23^{A}
	3	1.03 ± 0.10^{b}	0.99 ± 0.14^{b}	1.29 ± 0.05^{a}	0.66 ± 0.07^{c}	0.91 ± 0.08^{b}	0.97 ± 0.22^{A}
	Total means	1.01 ± 0.07^{A}	0.95 ± 0.08^{AB}	0.99 ± 0.32^{A}	0.61 ± 0.09^{C}	0.85 ± 0.05^{B}	0.88 ± 0.21
Springiness (mm)							
	Fresh	12.48 ± 0.50^{a}	14.55 ± 0.97^{a}	7.34 ± 0.77^{b}	5.75 ± 1.39^{b}	4.96 ± 1.07^{b}	9.02 ± 4.03^{A}
	1	12.73 ± 1.38^{a}	14.90 ± 1.32^{a}	7.73 ± 1.15^{b}	5.98 ± 1.35^{b}	5.12 ± 0.54^{b}	9.29 ± 4.11^{A}
	2	13.13 ± 0.48^{b}	15.25 ± 1.03^{a}	8.08 ± 0.83^{c}	6.28 ± 0.39^{d}	5.50 ± 0.38^{d}	9.64 ± 4.04^{A}
	3	13.35 ± 0.77^{a}	15.49 ± 0.84^{a}	8.39 ± 1.06^{b}	6.70 ± 1.05^{bc}	5.77 ± 0.89^{c}	9.94 ± 4.02^{A}
	Total means	12.92 ± 0.82^{B}	15.05 ± 0.97^{A}	7.88 ± 0.92^{C}	6.18 ± 1.02^{D}	5.34 ± 0.74^{D}	9.47 ± 3.96
Gumminess (N)							
	Fresh	4.30 ± 0.29^{a}	2.40 ± 0.18^{b}	3.60 ± 0.38^{a}	2.80 ± 0.39^{b}	2.50 ± 0.08^{b}	3.12 ± 0.79^{D}
	1	5.00 ± 0.75^{b}	2.97 ± 0.64^{c}	7.40 ± 0.51^{a}	3.59 ± 0.18^{c}	3.12 ± 0.07^{c}	4.41 ± 1.76^{C}
	2	7.20 ± 0.62^{a}	3.95 ± 0.36^{c}	6.27 ± 0.73^{ab}	6.09 ± 0.40^{ab}	5.62 ± 0.60^{b}	5.82 ± 1.20^{B}
	3	9.02 ± 0.66^{a}	6.21 ± 0.98^{b}	8.98 ± 0.29^{a}	9.20 ± 0.65^{a}	8.72 ± 0.83^{a}	8.42 ± 1.30^{A}
	Total means	6.38 ± 2.01^{A}	3.88 ± 1.61^{C}	6.56 ± 2.09^{A}	5.42 ± 2.64^{B}	4.99 ± 2.59^{B}	5.44 ± 2.36
Chewiness (mj)							
	Fresh	28.04 ± 1.46^{a}	16.26 ± 1.00^{d}	27.12 ± 0.77^{ab}	24.65 ± 1.21^{b}	20.54 ± 0.96^{c}	23.32 ± 4.63^{D}
	1	35.74 ± 2.14^{a}	24.06 ± 0.37^{c}	34.64 ± 1.39^{ab}	31.14 ± 0.89^{b}	25.84 ± 1.58^{c}	30.28 ± 4.95^{C}
	2	55.85 ± 2.20^{a}	35.08 ± 0.53^{e}	50.87 ± 1.29^{b}	46.40 ± 0.71^{c}	41.07 ± 0.82^{d}	45.85 ± 7.60^{B}
	3	73.97 ± 1.28^{a}	58.58 ± 1.47^{b}	70.88 ± 1.63^{a}	70.36 ± 0.78^{a}	57.07 ± 1.42^{b}	66.17 ± 7.27^{A}
	Total means	48.40 ± 18.77	33.49 ± 16.68^{E}	45.88 ± 17.57^{B}	43.13 ± 18.38^{C}	36.13 ± 14.92^{D}	41.40 ± 17.68

$^{a-d}$Means within a row with different superscripts and means with different superscript at the last column differ ($p \leq 0.05$), Control (C): Young and aged Ras cheese, T1: Aged Ras cheese+Camel cheese base (70%), T2: Aged Ras cheese+Camel cheese base (70%)+1% quinoa flour, T3: Aged Ras cheese+Camel cheese base (61.5%)+3% quinoa flour, T4: Aged Ras cheese+Camel cheese base (48.2%)+5% quinoa flour

Table 6: Color properties means±SD of LF-CMPCS during storage period at 5±1°C

		Treatments					
Color values	Storage period (months)	C	T1	T2	T3	T4	Total means
L*	Fresh	82.45±1.23^{a}	79.39±1.50^{ab}	77.92±1.67^{bc}	74.10±1.15^{cd}	70.94±1.99^{d}	79.96±4.37^{C}
	1	87.11±1.00^{a}	81.13±0.88^{b}	82.84±1.48^{b}	80.91±1.33^{b}	75.13±0.88^{c}	81.42±4.11^{D}
	2	88.15±0.61^{a}	81.20±0.95^{b}	83.56±0.87^{b}	81.80±1.55^{b}	77.12±0.73^{c}	82.36±3.80^{AB}
	3	89.22±0.86^{a}	81.37±1.12^{cd}	84.39±0.70^{b}	82.85±1.60^{bc}	79.36±0.42^{d}	83.43±3.55^{A}
	Total means	86.73±2.82^{A}	80.77±1.28^{C}	82.17±2.84^{B}	79.72±3.78^{C}	75.63±3.38^{D}	81.05±4.60
a*	Fresh	0.98±0.11^{a}	-2.51±0.29^{c}	0.01±0.05^{b}	0.38±0.06^{b}	0.89 ±0.100^{a}	-0.05±1.33^{A}
	1	-0.19±0.02^{ab}	-2.19±1.87^{b}	-0.26±0.05^{ab}	0.82±0.06^{a}	1.19 ±0.13^{a}	-0.13±1.41^{A}
	2	-0.15±0.04^{c}	-1.96±0.05^{d}	-0.23±0.08^{c}	0.99±0.18^{b}	1.28±0.07^{a}	-0.01±1.18^{A}
	3	-0.12±0.07^{b}	-1.73±0.12^{c}	-0.17±0.04^{b}	1.15±0.04^{a}	1.34±0.20^{a}	0.09±1.15^{A}
	Total means	0.13±0.52^{B}	-2.09±0.86^{C}	-0.16±0.11^{B}	0.83±0.31^{A}	1.18±0.21^{A}	-0.02±1.24
b*	Fresh	12.33±0.83^{b}	12.22±0.86^{b}	15.82±1.60^{ab}	17.16±1.88^{a}	16.73 ±1.64^{a}	14.85±2.53^{C}
	1	14.03±0.38^{b}	15.03±0.41^{b}	15.56±0.60^{b}	17.55±0.71^{a}	17.79±0.68^{a}	15.99±1.58^{B}
	2	15.22±0.97^{a}	16.15±1.01^{a}	16.90±1.84^{a}	18.01±0.39^{a}	18.29±1.05^{a}	16.91±1.53^{AB}
	3	16.38±0.75^{a}	17.35±1.13^{a}	18.12±0.76^{a}	18.64±0.99^{a}	18.97±1.86^{a}	17.89±1.38^{A}
	Total means	14.49±1.69^{C}	15.19±2.12^{C}	16.60±1.54^{B}	17.84±1.23^{A}	17.94±1.46^{A}	16.41±2.01
C*	Fresh	12.37±1.01^{b}	12.48±0.15^{b}	15.82±1.17^{a}	17.16±0.58^{a}	16.65±0.43^{a}	14.89±2.23^{D}
	1	14.00±0.05^{c}	15.19±0.61^{c}	15.56±0.33^{bc}	17.57±0.62^{ab}	17.83±1.58^{a}	16.03±1.66^{C}
	2	15.22±0.56^{b}	16.27±0.62^{ab}	16.90±1.65^{ab}	18.04±0.71^{ab}	18.33±1.08^{a}	16.95±1.46^{B}
	3	16.38±1.02^{b}	17.44±0.86^{ab}	18.12±0.58^{ab}	18.68±1.03^{ab}	19.02±0.66^{a}	17.92±1.21^{A}
	Total means	14.49±1.69^{C}	15.34±1.98^{C}	16.60±1.39^{B}	17.86±0.87^{A}	17.96±1.26^{A}	16.45±1.99
h_{ab}°	Fresh	85.46±1.10^{b}	-78.39±0.70^{c}	89.96±1.31^{a}	88.73±1.04^{a}	86.94±1.58^{ab}	54.54±68.82^{A}
	1	-89.22±0.86^{c}	-81.70±1.01^{b}	-89.04±0.35^{c}	87.32±0.63^{a}	86.17±0.48^{a}	-17.29±87.97^{B}
	2	-89.43±1.07^{c}	-83.08±0.74^{b}	-89.22±0.60^{c}	86.85±1.49^{a}	86.00±0.64^{a}	-17.78±88.10^{B}
	3	-89.58±1.22^{c}	-84.31±1.06^{b}	-89.46±0.77^{c}	86.47±1.17^{a}	85.96±1.70^{a}	-18.18±88.26^{B}
	Total means	-45.69±79.07^{C}	-81.87±2.43^{D}	-44.44±81.04^{B}	87.34±1.31^{A}	86.26±1.13^{A}	0.32±87.45
WI*	Fresh	78.53±1.17^{a}	75.91±1.53^{ab}	72.84±1.60^{b}	68.93±1.68^{c}	66.51±0.84^{c}	72.54±4.70^{B}
	1	80.97±1.32^{a}	75.78±1.53^{b}	76.83±1.61^{b}	74.06±0.81^{b}	69.40±0.89^{c}	75.40±4.04^{A}
	2	80.71±1.49^{a}	75.14±0.89^{b}	76.42±0.80^{b}	74.38±1.16^{b}	70.68±1.57^{c}	75.46±3.51^{A}
	3	80.39±1.04^{a}	74.48±1.23^{bc}	76.08±0.42^{b}	74.64±1.50^{bc}	71.93±1.68^{c}	75.50±3.07^{A}
	Total means	80.15±1.47^{A}	75.32±1.28^{B}	75.54±1.94^{B}	73.00±2.71^{C}	69.63±2.37^{D}	74.73±3.99
ΔE	Fresh	0.00	4.64±0.28^{d}	5.80±0.44^{c}	9.66±0.71^{b}	12.29±0.34^{a}	6.47±4.39^{B}
	1	5.09±0.17^{cd}	6.39±0.06^{bc}	4.55±0.30^{d}	7.22±0.24^{b}	12.64±1.39^{a}	7.17±3.04^{A}
	2	1.60±0.20^{d}	7.24±0.03^{b}	4.89±0.67^{c}	7.03±0.18^{b}	11.54±0.86^{a}	6.46±3.39^{B}
	3	8.23±0.12^{b}	2.69±0.23^{d}	2.84±0.21^{d}	5.74±0.46^{c}	10.30±0.64^{a}	5.96±3.10^{C}
	Total means	3.73±3.32^{E}	5.24±1.83^{C}	4.52±1.18^{D}	7.41±1.52^{B}	11.69±1.20^{A}	6.51±3.46
Browning index (BI*)	Fresh	16.51±0.99^{c}	13.77±1.41^{c}	21.91±1.66^{b}	25.80±0.68^{a}	26.72±1.36^{a}	20.94±5.36^{C}
	1	16.75±0.64^{d}	17.74±0.39^{d}	19.85±0.94^{c}	24.36±0.78^{b}	27.27±0.69^{a}	21.19±4.19^{C}
	2	18.17±0.35^{c}	19.58±1.22^{bc}	21.60±1.32^{b}	24.91±1.55^{a}	27.38±1.13^{a}	22.32±3.65^{B}
	3	19.48±0.79^{d}	21.53±1.18^{cd}	23.17±0.81^{bc}	25.64±1.25^{ab}	27.63±1.28^{a}	23.49±3.13^{A}
	Total means	17.72±0.99^{D}	18.15±3.14^{D}	21.63±1.62^{C}	25.17±1.13^{B}	27.25±1.04^{A}	21.98±4.19

$^{a-d}$Means within a row with different superscripts and means with different superscript at the last column differ ($p \leq 0.05$), L*: Value is an indicator of luminosity (the degree of lightness from black to white), a*: Value is an indicator of green (–) and red (+), b*: Indicator of blue (–) and yellow (+), C*: Color intensity, h_{ab}°*: Hue angle, WI*: Whiteness index, ΔE: Total color difference, BI*: Browning index, *Expressed as the percentage difference between the area of the melted and the original disc of cheese sample, Control (C): Young and aged Ras cheese, T1: Aged Ras cheese+Camel cheese base (70%), T2: Aged Ras cheese+Camel cheese base (70%)+1% quinoa flour, T3: Aged Ras cheese+Camel cheese base (61.5%)+3% quinoa flour, T4: Aged Ras cheese+Camel cheese base (48.2%)+5% quinoa flour

during the storage period. These results agree with Do Egypto Queiroga *et al.*[39]. On the other hand, higher green component (a*) values were found in T4 followed by T3 and T2. while the lowest value recorded in the control sample. The same trend was noticed during the storage period. The addition of quinoa flour may be affected the color of experimental cheese, these results agree with Park[40] and Lucas *et al.*[41]. The b* values (yellow component) of fresh LF-CMPCS were found to be higher ($p \leq 0.05$) significantly in T4 followed by T3 and control. Similar results were observed during the storage period. Hue angle (hab) values of LF-CMPCS supplemented with quinoa flour were significantly ($p \leq 0.05$) different and ranged from 86.94-89.96°. The significant ($p \leq 0.05$) decrease in the WI of fresh and storage LF-CMPCS supplemented with quinoa flour were detected for T4, T3 and T2. The values are presented in Table 6. Total color difference values (ΔE) increased with the increase of quinoa flour concentration in cheeses while decreased during storage periods. Also, reduction in the browning index (BI*) of LF-CMPCS supplemented with quinoa flour were observed Table 6.

Fatty acids analysis: The fatty acid concentrations of LF-CMPCS are presented in Table 7. The results showed significant ($p\leq 0.05$) increasing in Linoleic acid (18:2), α-Linolenic (18:3), also known as Omega-6 and Omega-3 and Eicosenoic (20:1) in the treatments T4, T3, T2 and T1 respectively compared with the control samples. However, there is an increase ($p\leq 0.05$) in the concentration of long- chain fatty acids, except for linolenic acid, which increased ($p\leq 0.05$) significantly with the increase of the ratio of quinoa flour. Also, there was a significant ($p\leq 0.05$) increase in the palmitoleic (16:1) concentration in These results could be attributed to the elevated level of those fatty acids in the quinoa flour. Also, there was an increase ($p\leq 0.05$) in the Palmitoleic (16:1) concentration in treatments T4, T3, T2 and T1 compared to the control. Similar results were reported before on the storage cheese[42,43].

Volatile fatty acids (VFA) (C6:C10) concentration was higher in the control and T1 than T2, T3 and T4. However, results showed a significant ($p\leq 0.05$) increase in Σ monounsaturated fatty acid (MUFA). The concentration of Σ polyunsaturated fatty acids (PUFA) increased ($p\leq 0.05$) significantly with the increase of the quinoa flour. It can be noticed that T4 recorded the highest value, followed by T3 and T2, while control and T1 recorded the lowest values. Also, the concentration of Σ unsaturated fatty acids (USFA) increased ($p\leq 0.05$) significantly with the increase of quinoa flour it can be noticed that T4 recorded the highest value followed by T3 and T2 while control and T1 recorded the lowest values. The same trend observed in the concentration of ΣUSFA/ΣSFA. An opposite trend was observed in the concentration of ΣSFA/ΣUSFA and the concentration of oleic/linoleic (O/L). The ratio of omega-6/omega-3 recorded a higher concentration. The values were 2.07:1, 2.03:1 and 2.03:1 for T4, T3 and T2 respectively, while in the control and T1 samples recorded the lowest concentration. These results were due to the high levels of linoleic acid (18:2) and α-linolenic (18:3) acids in the quinoa flour[11].

Minerals content of fresh low-fat camel milk processed cheese spread: Results of minerals content of fresh LF-CMPCS supplemented with quinoa flour are shown in Table 8. The results indicate that the supplementation with quinoa flour caused significant ($p\leq 0.05$) decreased in the minerals content of LF-CMPCS supplementation with quinoa flour. However, the control sample had higher minerals content than T1, T2, T3 and T4, respectively. Results from Table 8 showed that cheese samples T4, T3 and T2 are significantly ($p\leq 0.05$) higher in the content of potassium, phosphorus, magnesium and calcium,

Table 7: Free fatty acids composition means±SD (FFA% as relative area percentage) of LF-CMPCS after 3 months of storage at 5±1°C

	Treatments				
Fatty acids	C	T1	T2	T3	T4
Caproic (C6)	1.12±0.08^{a}	0.41±0.07^{b}	0.33±0.04^{bc}	0.26±0.05^{c}	0.22±0.03^{c}
Caprylic (C8)	1.17±0.05^{a}	0.37±0.05^{b}	0.30±0.03^{bc}	0.24±0.06^{bc}	0.21±0.03^{c}
Capric acid (C10:0)	2.24±0.09^{a}	1.53±0.08^{b}	0.76±0.14^{c}	0.69±0.11^{c}	0.68±0.08^{c}
Lauric acid (C12:0)	2.58±0.45^{a}	1.97±0.20^{a}	1.02±0.06^{b}	1.09±0.20^{b}	1.07±0.13^{b}
Myristic acid (C14:0)	11.78±0.55^{a}	10.93±0.59^{ab}	10.78±0.43^{ab}	10.71±0.50^{ab}	9.98±0.47^{b}
Pentadecylic acid (C15:0)	1.77±0.35^{a}	1.12±0.13^{b}	0.71±0.06^{b}	0.65±0.13^{b}	0.66±0.05^{b}
Palmitic acid (C16:0)	25.49±0.80^{a}	24.19±0.34^{a}	23.92±0.99^{a}	24.21±0.63^{a}	24.07±0.68^{a}
Palmitoleic (16:1)	1.08±0.10^{b}	12.53±1.28^{a}	12.05±0.20^{a}	11.60±0.58^{a}	11.79±0.51^{a}
Margaric acid (C17:0)	6.53±0.42^{a}	2.68±0.12^{b}	1.23±0.18^{c}	1.18±0.09^{c}	1.11±0.13^{c}
Stearic acid (C18:0)	9.24±0.32^{b}	13.09±0.84^{a}	13.91±1.53^{a}	13.11±0.86^{a}	13.03±0.15^{a}
Arachidic acid (C20:0)	5.70±0.45^{a}	0.57±0.04^{b}	0.36±0.06^{b}	0.31±0.03^{b}	0.27±0.06^{b}
Oleic acid (18:1)	28.20±0.62^{a}	26.35±0.79^{ab}	23.82±1.50^{b}	24.57±0.73^{b}	24.73±0.88^{b}
Linoleic acid (18:2)	1.99±0.19^{c}	2.16±0.09^{c}	6.49±0.27^{b}	6.72±0.21^{ab}	7.14±0.25^{a}
α-Linolenic (18:3)	1.12±0.20^{c}	2.10±0.25^{b}	3.24±0.38^{a}	3.31±0.36^{a}	3.45±0.39^{a}
Eicosenoic (20:1)	Trace	Trace	1.12±0.20^{b}	1.35±0.14^{ab}	1.59±0.17^{a}
Volatile fatty acids	4.54±0.09^{a}	2.31±0.18^{b}	1.39±0.21^{c}	1.19±0.26^{c}	1.11±0.14^{c}
Saturated fatty acids (SFA)	67.62±3.43^{a}	56.86±2.08^{b}	53.32±3.50^{b}	52.45±2.66^{b}	51.31±1.75^{b}
Monounsaturated acids (MUFA)	29.28±0.72^{b}	38.88±2.07^{a}	36.95±1.50^{a}	37.52±1.45^{a}	38.11±1.53^{a}
Polyunsaturated acids (PUFA)	3.11±0.01^{b}	4.26±0.34^{b}	9.73±0.65^{a}	10.03±0.47^{a}	10.59±0.60^{a}
Unsaturated fatty acids (USFA)	32.38±0.71^{c}	43.14±1.73^{b}	46.68±2.15^{ab}	47.55±1.92^{ab}	48.70±2.12^{a}
USFA/SFA	0.48±0.01e	0.76±0.02^{d}	0.87±0.02^{c}	0.91±0.02^{b}	0.95±0.01^{a}
SFA/USFA	2.09±0.06^{a}	1.32±0.01^{b}	1.14±0.02^{c}	1.10±0.01^{cd}	1.05±0.03^{d}
Oleic/Linoleic (O/L)	14.23±1.05^{a}	12.22±0.87^{b}	3.66±0.08^{c}	3.65±0.02^{c}	3.46±0.03^{c}
Omega-6/Omega-3	1.85:1^{a}	1.03:1^{b}	2.03:1^{a}	2.03:1^{a}	2.07:1^{a}

$^{a-d}$Means within a row with different superscripts and means with different superscript at the last column differ ($p\leq 0.05$), Control (C): Young and aged Ras cheese, T1: Aged Ras cheese+Camel cheese base (70%), T2: Aged Ras cheese+Camel cheese base (70%)+1% quinoa flour, T3: Aged Ras cheese+Camel cheese base (61.5%)+3% quinoa flour, T4: Aged Ras cheese+Camel cheese base (48.2%)+5% quinoa flour

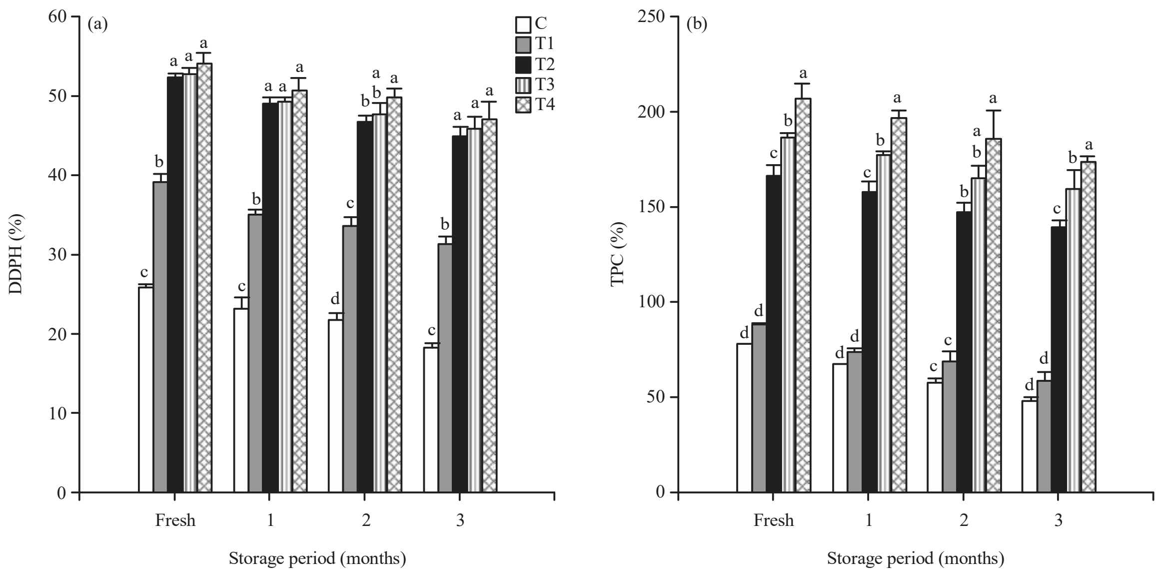

Fig. 2(a-b): Antioxidant activity (Radical scavenging activity) (a) DDPH and (B) Total phenolic compound (TPC) of LF-CMPCS during storage period at 5±1°C

Control (C): Young and aged Ras cheese, T1: Aged Ras cheese+Camel cheese base (70%), T2: Aged Ras cheese+Camel cheese base (70%)+1% quinoa flour, T3: Aged Ras cheese+Camel cheese base (61.5%)+3% quinoa flour, T4: Aged Ras cheese+Camel cheese base (48.2%)+5% quinoa flour

Table 8: Minerals content means±SD (mg /100 g) of fresh LF-CMPCS during fresh storage period at 5±1°C

	Treatments				
Minerals	C	T1	T2	T3	T4
Calcium	840.65±50.40^{a}	756.86±54.76^{a}	792.55±51.35^{a}	792.63±81.33^{a}	793.37±42.07^{a}
Magnesium	29.00±4.00^{b}	25.86±4.66^{b}	49.60±5.00^{a}	53.19±1.99^{a}	57.99±3.79^{a}
Sodium	726.88±24.38^{a}	597.40±85.80^{b}	532.26±29.96^{b}	532.17±18.97^{b}	533.01±21.71^{b}
Potassium	76.45±1.95^{a}	51.23±1.83^{b}	56.31±0.81^{b}	57.00±4.50^{b}	67.75±6.52^{a}
Iron	0.20±0.02^{c}	0.73±0.15^{a}	0.11±0.06^{c}	0.32±0.06^{bc}	0.54±0.10^{ab}
Copper	0.03±0.02^{b}	0.33±0.01^{a}	0.02±0.01^{b}	0.05±0.01^{b}	0.08±0.04^{b}
Manganese	Trace	0.21±0.04^{a}	0.21±0.08^{a}	0.25±0.02^{a}	0.27±0.08^{a}
Zinc	1.10±0.15^{b}	1.87±0.18^{a}	0.87±0.21^{b}	0.91±0.15^{b}	0.89±0.17^{b}
Chloride	1045.39±57.14^{a}	996.12±130.87^{a}	931.29±66.04^{a}	931.73±95.23^{a}	932.99±37.69^{a}
Phosphorus	508.93±19.68^{a}	490.86±89.61^{a}	481.95±56.59^{a}	489.95±26.70^{a}	497.71±78.48^{a}

$^{a-c}$Means within a row with different superscripts and means with different superscript at the last column differ ($p\leq0.05$), Control (C): Young and aged Ras cheese, T1: Aged Ras cheese+Camel cheese base (70%), T2: Aged Ras cheese+Camel cheese base (70%)+1% quinoa flour, T3: Aged Ras cheese+Camel cheese base (61.5%)+3% quinoa flour, T4: Aged Ras cheese+Camel cheese base (48.2%)+5% quinoa flour

iron and zinc than control and T1. Hager *et al.*[11] reported that the quinoa our had high phosphorus contents with concentrations up to 441.6 mg/100 g.

Antioxidant activity: The DPPH radical scavenging activity values and total phenolic compound of LF-CMPCS supplemented with quinoa flour were presented in Fig. 2a. The results showed that the radical scavenging activity (DPPH) increased ($p\leq0.05$) significantly with the increase of quinoa flour. The radical scavenging activity (DPPH) of T4 recorded the highest values followed by T3 and T2 while T1 and control recorded lower values. The same trend was observed in total phenolic compounds. Results from Fig. 2b indicate that total phenolic compounds of T4 recorded the highest values followed by T3 and T2 than T1 and control, which recorded the lowest values. On the other hand, the radical scavenging activity (DPPH) and total phenolic compounds TPC of all treatments decreased ($p\leq0.05$) significantly during the storage period. These results agree with those of Khalifa *et al.*[43] and Ondrejovic *et al.*[44].

Microstructure of fresh low-fat camel milk processed cheese spread: The microstructure of LF-CMPCS as affected by the formula of ingredients. As well as different concentrations of

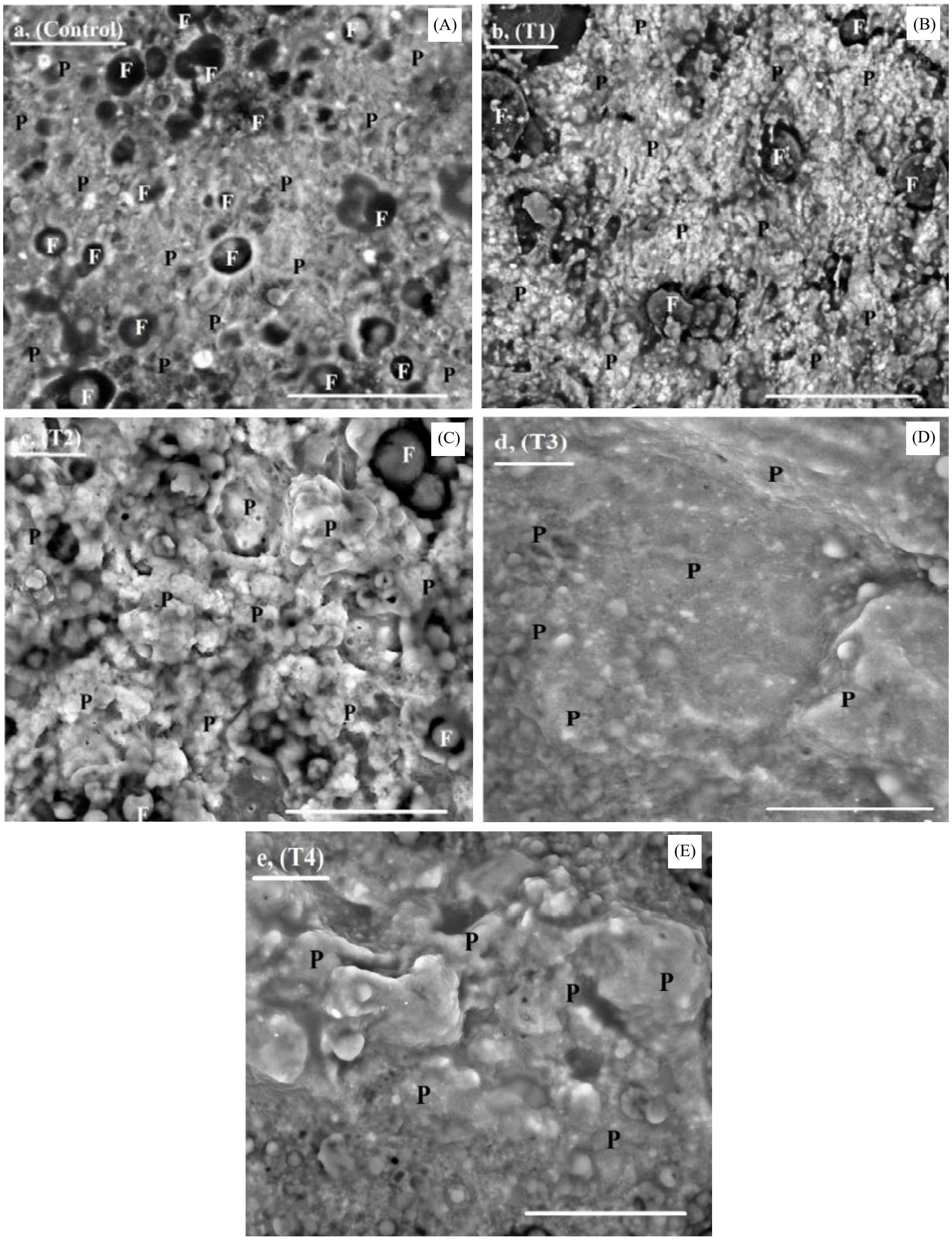

Fig. 3(a-e): Scanning electron microscope of fresh LF-CMPCS, (A) Control (C): Young and aged Ras cheese, (B) T1: Aged Ras cheese+Camel cheese base (70%), (C) T2: Aged Ras cheese+Camel cheese base (70%)+1% quinoa flour, (D) T3: Aged Ras cheese+Camel cheese base (61.5%)+3% quinoa flour and (E) T4: Aged Ras cheese+Camel cheese base (48.2%)+5% quinoa flour

P: Protein matrix, F: Fat gap, Scale bar: 100 µm, Magnification: 1000x

quinoa flour are shown in Fig. 3. Where Fig. 3a is the control, 3b is T1 and 3c is T2. The images indicated that T3 and T4 (Fig. 3d, e, respectively) have smoother and denser surface structure compare to the control and T1. Adding quinoa flour to the LF-CMPCS had more smoothly and systematically dispersed with less porosity in casein network[45]. The casein micelles were less defined. Scanning electron microscopy (SEM) of fresh LF-CMPCS with quinoa flour 5% (T4) showed a casein matrix as granular shape. SEM of LF-CMPCS with quinoa flour 5% (Fig. 3e) reflected the compact structure of the casein network. The addition of quinoa flour to low-fat camel processed cheese spread. The treatment 5% quinoa flour had higher hardness textures, while cohesion textures increased in the treatments of 1 and 3% of LF-CMPCS.

Figure 3 shows the main structure of LF-CMPCS. It indicated the interaction between casein particles and small fat globules, which were largely embedded in casein aggregates with whey forming with quinoa flour T2, T3 and T4 comparable with T1 and control large fat globules strong interaction between casein particles. These structures may have been responsible for the loss of cheese meltability. The protein matrix in T1 become more ragged, less homogenous and contained numerous small holes and cracks. These results agree with the finding of Mistry *et al.*[46], who observed fat globules of different sizes embedded in the continuous protein network. However, a porous assembly with relatively large pores was noted in the control cheese and more dense protein masses were also observed in cheeses made from 5% quinoa flour (T4). The structural matrix of spread processed cheese is a cross-linked casein-calcium phosphate network in which fat globules are physically entrapped, the protein matrix is elastic when the casein is largely intact[47]. Figure 3 shows the image of microstructural of the traditional processed cheese spread (control) and its analogs with 1-5% (T2-T4) quinoa flour with the same magnification 100x. The protein matrix is visible with various forms and sizes. Control processed cheese sample made from Ras cheese (Fig. 3a) revealed on an open network of aggregated proteins where the walls of the protein matrix are relatively solid with smaller aggregates have been joined directly by the stranded of fibrous protein material. SEM micrographs showed a uniform distribution of fat globules throughout the protein matrixes of all samples. But fat globules in cheese T1 were not embedded in the protein aggregates as they were in control one. The density of the protein network increases and pores, sized decreases in processed cheese spread fortified by quinoa flour 1-3% compared with T1 and control one with the decrease in pH. LF-CMPCS made with quinoa flour showed a protein matrix to be composed of a relatively uniform small particle in T1, T2, T3 and T4 (Fig. 3b-e). These differences in structure and hardness may be related to different ionic conditions, especially ionic calcium and phosphate during cheese processing[48]. Thus, LF-CMPCS fortified with different levels of quinoa flour consisted of a uniform dispersion of protein particles and fat globules interrupted only by occasional it by the SEM. Fat globules in control and T1 (Fig. 3a, b) in both types of processed cheese spreads were dispersed throughout the matrix but did not appear to interact with protein aggregate in the matrix as they are in cheese spread with quinoa flour. In cheese spread, T4 (Fig. 1e) revealed larger aggregates apparently by coarse structure and protein matrix. These account for the rough flavors of those cheeses, which had fewer scores than other cheeses.

Organoleptic properties: The data for the organoleptic properties of LF-CMPCS is presented in Table 9. The assessment was done by studying the main characteristics such as color, flavor, appearance, texture and overall acceptability of LF-CMPCS. The obtained data showed that flavor was significantly improved with the addition of quinoa flour. The flavor score for the different treatments was significant ($p<0.05$) compared to the control. The flavor of the produced cheese was improved by adding the quinoa flour. Body and texture score were improved with the increase of the quinoa flour ratio. The highest value was presented in T4 (36.95). Statistical analysis exhibited a significant difference ($p<0.05$) among all treatments compared to the control. Physicochemical properties of quinoa flour are used to enhance body and texture in the low-fat camel milk processed spread cheese as an emulsion, water-retention agents, stabilizers and thickeners. The appearance got a low score in T1 and control, while T4 and T3 showed the highest score. The increase in the quinoa ratio affected the appearance, the strength and the structure of the resultant cheese. The organoleptic evaluations showed that the treatments with quinoa flour at 3 and 5% (w/v) respectively had the highest overall acceptability because quinoa flour facilitates to produce a smooth texture and a good appearance. Overall the quality and acceptability of all treatments were reduced with the progress in the storage period. The means of values for the total score is presented in Table 9. These results agree with those obtained by Awad[38], El-Dardiry *et al.*[36] and Khalifa *et al.*[43]. This study revealed the significance of using quinoa flour in the production of low-fat camel milk processed cheese spread. This study encourages the future use of milk producers to manufacture and improve the quality of low-fat camel milk processed cheese spread. It is due to increasing the consumer demand for the product because of its nutritional and health benefits.

Table 9: Organoleptic properties mean±SD of LF-CMPCS during storage period at 5±1°C

Parameters	Storage period (months)	Treatments C	T1	T2	T3	T4	Total means
Appearance (20)							
	Fresh	17.84±1.34^{a}	18.80±1.30^{a}	18.14±0.64^{a}	19.49±0.99^{a}	19.15±1.15^{a}	18.68±1.13^{A}
	1	17.10±0.40^{a}	18.02±0.22^{ab}	17.95±0.95^{ab}	19.05±0.55^{a}	18.94±0.51^{a}	18.21±0.89^{AB}
	2	16.39±0.89^{a}	17.54±1.04^{a}	17.42±0.92^{a}	18.56±0.56^{a}	17.90±0.90^{a}	17.56±1.04^{BC}
	3	16.74±1.24^{a}	17.03±0.53^{a}	16.97±0.97^{a}	18.15±0.65^{a}	17.02±0.52^{a}	17.18±0.87^{C}
	Total means	17.01±1.05^{C}	17.85±1.01^{ABC}	17.62±0.89^{BC}	18.81±0.80^{A}	18.25±1.13^{AB}	17.91±1.13
Body and texture (40)							
	Fresh	37.15±1.15^{a}	37.99±2.55^{a}	37.86±1.36^{a}	39.91±0.41^{a}	38.97±0.97^{a}	38.37±9.72^{A}
	1	36.88±0.88^{a}	37.52±1.02^{a}	37.45±0.65^{a}	39.24±0.94^{a}	38.14±0.54^{a}	37.84±1.09^{A}
	2	35.92±1.32^{a}	36.74±1.04^{a}	36.40±1.20^{a}	38.65±1.15^{a}	37.50±0.80^{a}	37.04±1.37^{A}
	3	33.90±1.10^{b}	34.90±1.50^{ab}	35.52±1.37^{ab}	38.01±1.14^{a}	36.95±1.35^{ab}	35.85±1.87^{A}
	Total means	35.96±1.64^{A}	36.78±1.09^{A}	36.81±1.39^{A}	38.95±1.09^{A}	37.89±1.14^{A}	37.28±4.99
Flavor (40)							
	Fresh	38.73±0.23^{a}	37.86±0.86^{ab}	37.41±0.71^{b}	37.70±0.90^{ab}	37.30±0.94^{b}	37.80±1.19^{A}
	1	38.03±0.53^{a}	37.61±0.81^{a}	36.90±1.41^{a}	37.06±0.94^{a}	36.78±1.78^{a}	37.27±1.39^{AB}
	2	38.45±0.85^{a}	36.30±1.20^{a}	36.39±0.89^{a}	36.23±0.43^{a}	35.88±1.18^{a}	36.65±1.29^{BC}
	3	37.87±1.07^{a}	36.12±0.22^{ab}	35.92±1.12^{ab}	35.17±0.57^{b}	35.01±0.51^{b}	36.01±1.33^{C}
	Total means	38.27±0.95^{A}	36.97±1.02^{A}	36.66±1.07^{B}	36.54±1.17^{B}	36.24±1.36^{B}	36.93±1.48
Total (100)							
	Fresh	93.72±2.72^{a}	94.65±23.35^{a}	93.41±2.71^{a}	97.10±2.30^{a}	95.42±3.02^{a}	94.86±9.14^{A}
	1	92.01±1.01^{a}	93.15±2.05^{a}	92.30±3.00^{a}	95.35±0.55^{a}	93.86±2.86^{a}	93.33±2.09^{A}
	2	90.76±3.06^{a}	90.98±3.28^{a}	90.21±3.01^{a}	93.44±2.14^{a}	91.28±2.88^{a}	91.37±2.71^{B}
	3	88.51±3.41^{a}	88.05±2.25^{a}	88.41±3.46^{a}	91.33±2.36^{a}	88.98±2.38^{a}	89.05±2.63^{B}
	Total means	91.25±3.36^{B}	91.71±10.46^{B}	91.08±3.29^{B}	94.31±2.81^{A}	92.39±3.50^{A}	92.14±5.43

$^{a-c}$Means within a row with different superscripts and means with different superscript at the last column differ ($p \le 0.05$), Control (C): Young and aged Ras cheese, T1: Aged Ras cheese+Camel cheese base (70%), T2: Aged Ras cheese+Camel cheese base (70%)+1% quinoa flour, T3: Aged Ras cheese+Camel cheese base (61.5%)+3% quinoa flour, T4: Aged Ras cheese+Camel cheese base (48.2%)+5% quinoa flour

CONCLUSION

The results suggested that the quinoa flour could be used for LF-CMPCS production and quality improvement without altering the product properties. Overall, the addition of quinoa flour at 3% is recommended for LF-CMPCS production to augment the processed cheese quality acceptance, physiochemical, meltability, microstructure and organoleptic properties.

SIGNIFICANCE STATEMENT

This study discovers that the addition of quinoa flour to camel processed cheese formula resulted in the merger of casein micelles, therefore increasing the cohesion of the flat casein compared with a control sample. Low-fat camel milk cheese with 3% quinoa flour is recommended to improve the texture properties without altering the quality and the acceptability of the spread cheese product. This study will help the researcher to uncover the critical factors that many researchers were not able to explore for LF-CMPCS production using inexpensive protein alternatives. Thus, using quinoa flour or other alternative as a partially substitute for camel milk could reduce the cost of LF-CMPCS production with the same cheese quality.

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