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The Effect of Replacing Water with Tiger Nut Milk (*Cyperus Esculentus* L) on the Physicochemical Properties, Fatty Acid Profile and Meltability of Spreadable Processed Cheese

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TIGER nut milk (*Cyperus esculentus* L.) was used at three different levels (10, 20 and 30%) in the manufacture of spreadable processed cheese. The chemical composition, meltability, oil separation, total phenols, antioxidant activity, fatty acid profile, microbiological properties and sensory evaluation were determined. The chemical composition has been improved by usingtiger nut milk, and high meltability was observedin spreadable processed cheese with high levels of tiger nut milk (30%). Elevated values have been observed for both total phenols and antioxidant activity with cheese added to ittiger nut milk. In addition, cheese with added tiger nut milk gained high levels ofoleic acid, linoleic acid, and healthy polyunsaturated fatty acids. No microbial growths were detected in the processed cheese with 20 and 30 % tiger nut milk. As well all processed cheese samples with added tiger nut milk accepted by the panelists and cheese acceptability increased with the high level of tiger nut milk. Spreadable processed cheese with good quality attributes could be obtained by using tiger nut milk in its formulation up to level 30%, with acceptable impression.

Keywords: Spreadable processed cheese, Tiger nut milk, Phenolic content, Antioxidant activity, Fatty acid profile.

Introduction

Processed cheese is the most popular dairy product with high nutritional value and composed from natural cheese types with other ingredients. The natural cheese is the main ingredient which is inserted in the formulation of processed cheese with other dairy and nondairy ingredients in the presence of emulsifying salts under heating and continuous stirring to obtain uniform and smooth product with a prolonged shelf life (Kapoor & Metzger, 2008). Depending on the nature of ingredients present in the formulation, processed cheese may be considered as a hybrid product which contains both dairy and plant-based ingredients (non-dairy) to produce cheese with a uniform structureand pleasant flavor with health benefits (Grasso et al., 2021). Numerous studies have been made to improve the nutritional value, physical properties, functionality and texture of processed cheese depending on plant ingredients in different forms (Awad et al., 2014; Boukid et al., 2021; Khider et al., 2017; Talbot-Walsh et al., 2018; Tohamy et al., 2018). In addition, the plant-based products have gained more attention in recent years and consumers shifted their life style to a plant-base diet (Fehér et al., 2020). Hence, the economy must be directed to these products to produce healthy and suitable alternatives to animal-based food, even the incorporation of plant ingredients in healthier diet(Grasso et al., 2020). Plant ingredients are considered as functional components due to their content of phytochemicals, vitamins, mineralsand antioxidants beside their health benefits. Tiger nut (*Cyperus esculentus* L.) is a sweet almond-like tuber that has already been recognized as a high potential, alternative source of food nutrients (Kizzie-Hayford et al., 2016). It has been recognized for its health benefits and

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rich in nutrients such as protein, fiber, natural sugars, vitamins (E and C) and minerals. Tiger nut can contribute to the risk reduction of several diseases (coronary heart disease, arteriosclerosis, colon cancer and reduced the cholesterol level) (Adejuyitan, 2011). Upon extraction, tiger nut can produce milk with valuable content of protein, fat, carbohydrate and other phytochemicals. This milk was considered as a medicinal drink due to its higher energy, diuretic, rich in phosphorus, potassium and vitamins. It has a pleasant nutty flavor which can improve the taste and flavor of the product (El-Shenawy et al., 2019).Tiger nut milk was not used in the production of processed cheese; therefore, this study was performed to evaluate the impact of tiger nut milk at three different levels (10, 20 and 30 %) on the physicochemical, microbiological, physical properties, fatty acid profile, total phenols, antioxidant activity and sensory propertiesof spreadable processed cheese during two months of cold storage period.

Materials and Methods

MaterialsThe ingredients used in the preparation of spreadable processed cheese (SPC) consisted of Ras cheese (22.16% protein, 25.65% fat, 1.29% carbohydrate, 45.47% moisture and 5.52% ash), cheddar cheese (25.36% protein, 33.70% fat, 1.51% carbohydrate, 34.16% moisture and 5.27% ash),skim milk powder (34.00% protein, 1.50% fat, 52.00% carbohydrate, 4.00% moisture and 8.50% ash), butter (82.00% fat, 16.00% moisture and 0.50% ash) and non-dairy ingredients (tiger nut milk) which all were obtained from local market. The emulsifying salt (tri-sodium citrate) was supplied by Sigma-Aldrich Co., Germany.

Methods

Preparation of the Tiger nut milk

Tiger-nut milk was prepared by sorting out all unwanted objects and other rotten nuts, washed and rinsed in distilled water and soaked overnight to soften the fiber. And the water is changed from 2-3 timesto avoid bad smell. Nine-hundred grams of tiger-nuts are added to two liters of warm water and it isblended several times. Then the mash is sieved twice with a piece of fine cloth to separate the extract. Then it is further strained to obtain a fine consistency. The filtered extract is heated to 90°C for 15 minutes, cooled to 4°C and refrigerated for further processes (Belewu & Belewu, 2007).

Experimental procedures of processed cheese

The spreadable processed cheese (SPC) samples were prepared in the Laboratory of Dairy Department, Faculty of Agriculture, Fayoum University. The SPC samples were prepared by mixing different varieties of cheese (Ras, cheddar), butter, tri-sodium citrate, water and tiger nut milk according to the method used by Rafiq & Ghosh (2017), with some modifications. The formula of SPC consists of 51.20% cheese, 10.30% butter, 5% skim milk powder, 3% tri-sodium citrate and 30.50% water. In brief, cheese types and butter were placed with a portion of an aqueous solution of tri-sodium citrate in a double jacketed tank,and during heating to95 °C.Different levels of Tiger nut milk (10, 20 and 30 %) were used to replace the water in the cheese formula. The tiger nut milk is added while the mixture is heated and added the remaining portion of the aqueous solution of tri-sodium citrate with constant stirring. Cooking was performed for 15 min until a homogenous and uniform mixture was obtained, then placed in containers for cooling and was transferred to refrigerator till further analysis.

Methods of analysis

Chemical analysis

The chemical composition of different SPC samples including moisture, fat, protein, carbohydrate, fiber and ash were determined by the methods described in AOAC (2005). Dry matter (DM) and Fat/DM were calculated, while the pH values of SPC samples were measured using digital pH meter with a glass electrode Model pH (Kent EIL 7020).

Physical properties

The physical properties of SPC samples such as meltability and oil separation were measured according to the method described by Abbas et al. (2021).

Free fatty acids

Free fatty acids profile of SPC samples was estimated according to Laurens et al. (2012) using gas chromatography-mass spectrometry instrument (TRACE Ultra Gas Chromatographs, THERMO Scientific Corp., Santa Clara, CA, USA), coupled with a thermos mass spectrometer detector (ISQ Single Quadrupole, Mass Spectrometer). Analyses were carried out using helium as carrier gas at a flow rate of 1.0 mL/min and a split ratio of 1:10 using the following temperature program:60 ˚C for 1 min; rising at 4˚C/min to 240 ˚C and held for 1 min. The injector and detector were held at 210 °C.

Diluted samples (1:10 hexane) of 1 µL of the mixtures were injected, and the run time was 10 min. Mass spectra were obtained by electron ionization at 70 eV, using a spectral range of m/z 40–450.

Total phenols and antioxidant activity

Total phenols of SPC samples were determined according to Ozsoy et al. (2008), and the results were listed as mg GAE/g. The percentage of inhibition of total antioxidant activities of SPC samples were determined by the free radical DPPH method (Karaaslan et al., 2011).

Microbiological examination

Under aseptic conditions, mixed 1 gram of cheese samples with 1 ml sterilized sodium citrate solution (20%) and 8 ml of physiologic solution, to obtain the first dilution which used for making the further suitable dilutions required for the microbiological tests. All microbiological analysis were done according to Robinson (2005). Total viable counts (Log cuf/g) of cheese samples were enumerated byplate count agar medium, the plates were incubated at 35°C for 48h. Potato dextrose agar (PDA) medium was used for counting yeasts and molds, the plates were incubated at 25 ºC for 3-5 days. Coliform bacterial counts were determined on MacConkey agar media, the plates were incubated at 37°C for 24 hr.

Sensory evaluation

A nine-point hedonic scale was used for the sensory evaluation of SPC samples. The parameters; flavor, color, appearance, spreadability, firmness, creaminess and overall impression were evaluated as described by Cunha et al. (2010).

Statistical analysis

The results were statistically analyzed using general linear model of SPSS software (2007) and Duncan test was performed at P≤0.05. All data were collected in triplicate.

Results and Discussion

Chemical composition

The chemical composition of tiger nut milk (TNM) is presented in Fig, 1.

It was noted that TNM contained 86.95% moisture, 3.37% protein, 7.50% fat, 0.39% fiber, 0.48% ash and 1.31% carbohydrate. It was observed that TNM is obtained by the aqueous extraction of nuts and the composition of prepared milk is depended on the method of extraction and the amount of water used in extraction. In addition, its composition depends on the geographical origin of tiger nuts (Codina-Torrella et al., 2017). TNM was subjected for heat treatment for microbial and hygienic issues. It wasalso decided thattiger nuts are rich in carbohydrates including reducing sugars (7.40%), soluble sugars (7.40%), and starch (86.40%). In addition, nuts are rich in proteins of high biological value (7.00%) with considering amount of essential amino acids (Adedokun and Okorie, 2014). The prepared TNM has a nutty flavor and yellowish color. These results were consistent with El-Shenawy et al. (2019).

The chemical composition of SPC samples with different levels of tiger nut milk (TNM) is shown in Table 1. Tiger nut milk significantly (P≤0.05) affected the compositional analysis of SPC samples. The high level of TNM was affected the moisture content of SPC samples.

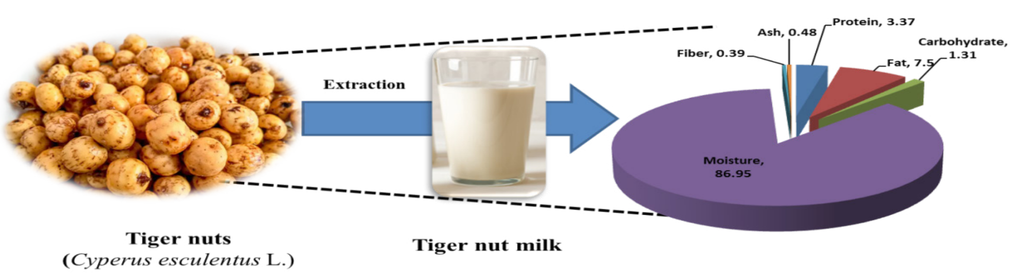

Fig. 1. Chemical composition of prepared tiger nut milk.

TABLE 1. Effect of partial substitution of water with different levels of tiger nut milk on chemical composition of SPC samples.

Parameters	Storage period (days)	Experimental treatments			
		SPC samples with tiger nut milk			
		T1	T2	T3	T4
Moisture	0	51.23^{a}±0.13	50.84d^{a}±0.41	50.19^{b}±0.25	49.71^{b}±0.22
	30	50.84^{a}±0.08	50.49^{a}±0.27	49.52^{b}±0.24	49.52^{b}±0.24
	60	50.84^{a}±0.08	50.49^{a}±0.27	49.91^{b}±0.42	49.52^{b}±0.24
DM	0	48.77^{b}±0.13	49.15^{b}±0.41	49.80^{a}±0.25	50.29^{a} ±0.22
	30	49.16^{b}±0.08	49.51^{b}±0.27	50.09^{a}±0.42	50.48^{a} ±0.24
	60	49.16^{b}±0.08	49.51^{b} ±0.27	50.09^{a} ±0.42	50.48^{a} ±0.24
Ash	0	4.86^{d}±0.10	5.01^{c}±0.07	5.14^{b} ±0.05	5.28^{a} ±0.05
	30	4.93^{d} ±0.06	5.09^{c} ±0.05	5.24^{b}±0.06	5.41^{a} ±0.09
	60	5.41^{d} ±0.06	5.09^{c}±0.06	5.24^{b}±0.06	5.41^{a} ±0.09
Protein	0	13.11^{c} ±0.10	13.50^{b}±0.16	13.79^{b} ±0.13	14.13^{a}±0.21
	30	13.29^{c}±0.11	13.65^{bc}±0.16	13.91^{ab}±0.32	14.22^{a} ±0.21
	60	13.29^{c}±0.11	13.65^{b}±0.16	13.91^{ab}±0.32	14.22^{a}±0.22
Fat	0	26.33^{c} ±0.29	27.17^{b} ±0.29	27.67^{b}±0.29	28.33^{a}±0.29
	30	26.70^{c}±0.00	27.50^{b}±0.00	27.83^{b}±0.29	28.67^{a} ±0.29
	60	26.29^{c}±0.00	27.50^{b} ±0.00	27.83^{ab} ±0.29	28.67^{a}±0.29
Fat/ DM	0	54.00^{b}±0.64	55.27^{ab}±0.78	55.55^{a}±0.82	56.34^{a}±0.63
	30	54.32^{c}±0.08	55.54^{b}±0.54	55.57^{b}±0.76	56.79^{a}±0.66
	60	54.32^{b} ±0.08	55.54^{a}±0.30	55.57^{a} ±0.76	56.79^{a}±0.66
pH	0	5.77^{b} ±0.06	5.80 ^{a} ±0.10	5.80^{a} ±0.06	5.87^{a} ±0.06
	30	5.67^{b} ±0.06	5.77^{a} ±0.06	5.80^{a} ±0.00	5.83^{a} ±0.06
	60	5.67^{b} ±0.06	5.78^{a} ±0.06	5.80^{a} ±0.00	5.83^{a} ±0.06

* Results are expressed as Mean ± SD; means with different superscripts in a row differ significantly (p ≤0.05).

T1= Spreadable processed cheese without tiger nut milk, T2= Spreadable processed cheese with 10% tiger nut milk, T3= Spreadable processed cheese with 20% tiger nut milk, T4= Spreadable processed cheese with 30% tiger nut milk.

The lowest moisture content 49.71% was obtained in T4 sample with high level of TNM, while the highest moisture content 51.23% was obtained in T1 sample without added TNM milk at fresh time of storage. This explains that TNM decreased the moisture content of cheese samples with the obvious impact of high levels. This is due to the increased dry matter content of the cheeseupon increasing the level of TNM and the evaporation of water during cooking might have a role in such effect. High moisture content (50.84 and 50.49%) has been observedat the end of the storage period for T1 and T2 samples respectively, while low moisture contents (49.91 and 49.52%) were obtained with T3 and T4 samples respectively. The moisture contentof all SPC samples is reducedduring storage which is due to the water loss from cheese containers during storage.The content of protein, fat, ash and fat/DM of SPC samples increases with an increasein the level of added TNM.There were significant differences (P≤0.05) in ash, protein, fat and fat/DM contents between SPC samples withdifferent TNM levels. As the level of TM increase, theses parameters increase. This is due to the total solid of TM and its content from such components and increasing the level of such parameters in all SPC samples during the storage period.These results are consistent withBalogun et al. (2019). Tiger nut milk may affect the values ofpH of SPC samples. There were significant differences (P≤0.05) between T1 and other samples. TNM milk may increase the acidity values of cheese, and there were no significant differences (P≤0.05) among samples with the addition ofTNM. High pH values of SPC samples withthe addition of TNM milkmay be due to the alkali effect of TNM, which affects the pH value of cheese mixture. The results were in accordance with Ajayi Adebola et al. (2023).

Physical properties

Tiger nut milk significantly (P≤0.05) affected the meltability and oil separation of different SPC samples as shown in Table 2. It was observed that TNM increased meltability of SPC samples and the meltability increases with the increase of added TNM level. The highest meltability (63.40 mm) was detected with T4 sample followed by T3 (63.26 mm)and T2 (60.21 mm), while the lowest meltability (59.04 mm) was detected in T1 sample at fresh time as shown in Fig 2. Meltability increases during storage in SPC samples treated with TNM. It is noticeable from Fig 2, T3 and T4 samples which containedhigher level of TNM showed comparable and higher meltability and observed anapparent improvement. The higher meltability in SPC samples is due to the fact that TNM had a valuable amount of starchy carbohydrate which might improve the interactions between TNM components and cheese proteins in addition to the higher pH of cheese matrix.

Tiger nuts are rich in carbohydrates, from which are 86.40% starch which could affect the meltability of SPC samples (Adedokun &Okorie, 2014). On the other hand, oil separation decreased with increasing the level of TNM. The higher percentage of oil separation may be observedwith T1 samplewhen compared to other SPC samples. The lower oil separation index in SPC samples is due to the protein-protein interactions in cheese matrix which affect these physical parameters of cheese(Abdeen et al., 2018). In addition, the state of cheese protein and the level of protein hydration may be also affect the structure and the spreadability of cheese (Piska &Št□tina, 2004). Moreover, the physical state of cheese network may be also be affected (Abdeen et al., 2018).

Phenolic contents and antioxidant activity

Table 3 shows the effect of TNM on total phenol content and antioxidant activity of SPC samples. The addition of TNM improved the phenolic profile and antioxidant activity of SPC samples. The total phenolic rate increases with an increase in the level of added TNM milk. The highest phenol content (3.05 mg Gallic/g) was observed in T4 sample, followed by T3 and T2 samples with (2.27 and 1.73 mg Gallic/g) respectively. It has been observed that the lowest phenol content (0.74 mg Gallic/g) in T1 sample. In addition, to increase the antioxidant activity of SPC samples with increasing levelof TNM.

T4 sample obtained the highest antioxidant

TABLE 2. Effect of partial substitution of water with different levels of tiger nut milkon physical properties of SPC samples.

Parameters	Storage period (days)	Experimental treatments SPC samples with tiger nut milk T1	T2	T3	T4
Meltability (mm)	0	59.04^{b}±0.25	60.21^{b}±0.91	63.26^{a}±0.72	63.40^{a}±0.47
	30	59.69^{c}±0.81	61.37^{b}±0.39	65.21^{a}±0.09	65.35^{a}±0.13
	60	60.36^{c} ±0.36	62.19^{b}±0.58	66.14^{a} ±0.52	66.20^{a}±0.52
Oil Separation %	0	50.37^{a}±0.34	46.46^{b} ±0.27	41.65^{c}±0.25	37.74^{d}±0.24
	30	49.73^{a}±0.68	44.51^{b}±0.23	38.35^{c}±0.26	33.91^{d}±0.07
	60	49.07^{a}±0.74	43.31^{b}±0.15	37.18^{c}±0.06	31.20^{d}±0.09

* Results are expressed as Mean ± SD; means with different superscripts in a row differ significantly (p ≤0.05). T1= Spreadable processed cheese without tiger nut milk, T2= Spreadable processed cheese with 10% tiger nut milk, T3= Spreadable processed cheese with 20% tiger nut milk, T4= Spreadable processed cheese with

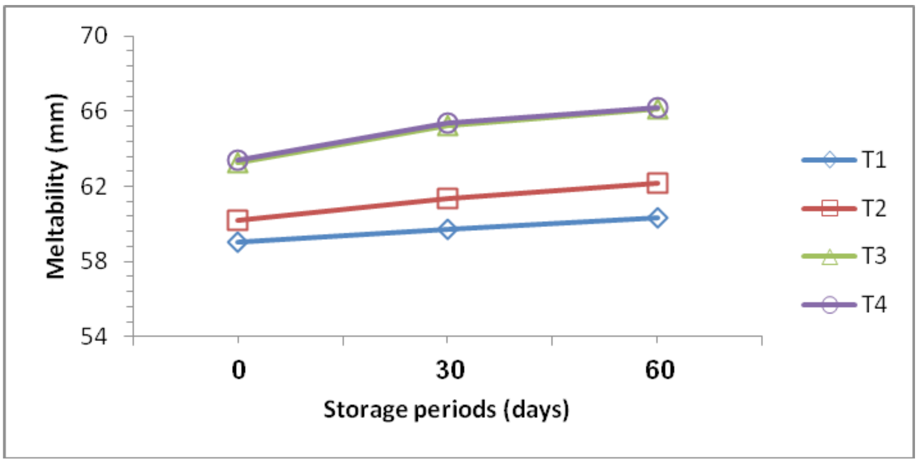

Fig. 2. Meltability of different SPC samples during storage periods.

TABLE 3. Effect of partial substitution of water with different levels of tiger nut milkon total phenols and antioxidant activity of SPC samples.

Parameters	Experimental treatments			
	SPC samples with tiger nut milk			
	T1	T2	T3	T4
Total phenols mg Gallic/g	0.74^{d} ±0.02	1.73^{c} ±0.15	2.27^{b}±0.33	3.05^{a} ±0.24
Antioxidant activity (%)	41.45^{d}±0.21	57.17^{c} ±3.24	63.14^{b} ±0.27	81.90^{a} ±0.49

* Results are expressed as Mean ± SD; means with different superscripts in a row differ significantly ($p \leq 0.05$).
T1= Spreadable processed cheese without tiger nut milk, T2= Spreadable processed cheese with 10% tiger nut milk, T3= Spreadable processed cheese with 20% tiger nut milk, T4= Spreadable processed cheese with 30% tiger nut milk

activity (81.90%), while it was notedthe lowest antioxidant activity (41.45%) with T1 sample. This could be attributed to the valuable content of polyphenols in TNM. It was reported that TNM has a high content of phytochemical substances which are responsible for its antioxidant activity (Bilikis &Olanrewaju, 2015; Razola-Díaz et al., 2022).This maypromote the use of TNM as functional ingredient in processing food.

Fatty acid profile

The fatty acid profile of different SPC samples is shown in Table 4. It was obvious that TNM enhanced the fatty acid profile of SPC samples and there were comparable values of fatty acids between all SPC samples. Short chain and long chain saturated fatty acids were found in comparable levels even at higher level of TNM.In addition to the presence of monounsaturated fatty acids also in comparable levels. On the other hand, the higher level of polyunsaturated fatty acids was observed in SPC samples treated with TNM. The highest level of oleic acid (26.63%) was detected with T4, while the lowest oleic acid (24.14%) was observed in T1. Moreover, the level of linoleic acid was higher in SPC samples treated with TNM. The higher level of linoleic acid (2.13%) was detected with T4, while the lower level of linoleic acid (1.86%) was observed in T1. These results are due to higher level of polyunsaturated fatty acids in TNM fats. Tiger nut was considered as a good source of healthy fats. This is because it containsaround 73% monounsaturated fat, 9% polyunsaturated fat and 18 % saturated fat. It is rich of oleic acid and linoleic acid with health benefits. Oleic acid can enhance the HDL cholesterol and lowering the LDL cholesterol which can help for preventing cardiovascular diseases (Okoroafor & Umeh, 2021).

Microbiological examination

It was found that TNM affected the total viable count (TVC) of SPC samples as presented in Table 5. Higher TVC was observed in T1 sample and the number increase during storage. T1 obtained ($7.00x10^{3}$ cfu/g) at fresh time, while it increased to ($36.00x10^{3}$ cfu/g) after two months of storage. There were no viable counts in SPC samples at fresh time, while T2 obtained ($1.33x10^{3}$ cfu/g) after one month of storage which increased to ($2.00x10^{3}$ cfu/g) after two months of storage. There were no viable bacterial counts in T3 and T4 either at fresh or after two months of storage. This may be due to the bacteriostatic effect of TM. No coliform, yeast and molds counts were detected in all SPC samples, which may be due to the hygienic conditions performed during the production of SPC.

Sensory properties

Results indicated that TNM had no significant effect on the sensorial evaluation of different SPC samples as shown in Table 6. This could explain the ability of using TNM in the production of SPC with acceptable scores comparable to SPC samples free from TNM. Although, higher scores of appearances, color and flavor were observed in SPC samples treated with TM. In addition, the texture of SPC samples was improved by using TNM even at higher level. Creaminess, firmness and spreadability were observed in higher values in SPC samples with TM when compared to T1 sample. This could be explained by the fact that TNM has a pleasant taste and flavor which can be comfortably consumed. Improvements in all sensory parameters were detected with SPC samples during storage. The overall impression is shown in Fig 3, which confirms that TNM had an apparent effect on the acceptability of SPC. At the end of storage period, the highest score was obtained in SPC sample with higher levels of TNM.

TABLE 4. Effect of partial substitution of water with different levels of tiger nut milk on fatty acid profile of SPC samples.

Fatty acids	Experimental treatments SPC samples with tiger nut milk				
Saturated fatty acids Short chain FAs (SCFAs)	**Carbon atoms**	**T1**	**T2**	**T3**	**T4**
Butyric acid	**C4:0**	1.50	1.69	1.55	1.54
caproic acid	**C6:0**	1.18	1.27	1.19	1.19
Caprylic acid	**C8:0**	0.82	0.84	0.81	0.81
Capric acid	**C10:0**	1.98	2.10	2.02	2.00
Lauric acid	**C12:0**	3.13	3.13	2.99	2.96
Long chain FAs (LCFAs)					
Myristic acid	**C14:0**	11.08	10.84	10.73	10.53
Pentadecanoic acid	**C15:0**	1.49	1.43	1.44	1.42
Palmitic acid	**C16:0**	34.37	34.18	33.87	33.14
Margaric acid	**C17:0**	0.97	0.83	0.89	0.86
Stearic acid	**C18:0**	12.89	12.81	12.75	12.48
Arachidic acid	**C20:0**	1.26	1.07	1.24	1.20
Unsaturated fatty acids Monounsaturated fatty acids (MUFAs)					
Myristoleic acid	**C14:1**	0.86	0.84	0.81	0.82
Palmitoleic acid	**C16:1**	1.68	1.64	1.63	1.59
Polyunsaturated fatty acids (PUFAs)					
Oleic acid	**C18:1**	24.14	24.58	25.28	26.63
Linoleic acid	**C18:2**	1.86	2.01	2.1	2.13
Linolenic acid	**C18:3**	0.67	0.63	0.64	0.65
EPA	**C20:5**	0.11	0.07	0.07	0.09

T1= Spreadable processed cheese without tiger nut milk, T2= Spreadable processed cheese with 10% tiger nut milk, T3= Spreadable processed cheese with 20% tiger nut milk, T4= Spreadable processed cheese with 30% tiger nut milk

TABLE 5. Effect of partial substitution of water with different levels of tiger nut milkon total viable count of SPC samples.

Parameters	Storage periods (days)	Experimental treatments SPC samples with tiger nut milk			
		T1	**T2**	**T3**	**T4**
TVC10^3× (cfu/g)	**0**	7.00^a±2.00	ND	ND	ND
	30	13.67^a ±3.51	1.33^b±1.53	ND	ND
	60	36.00^a ±6.25	2.00^b±1.00	ND	ND

* Results are expressed as Mean ± SD; means with different superscripts in a row differ significantly ($p \leq 0.05$).
T1= Spreadable processed cheese without tiger nut milk, T2= Spreadable processed cheese with 10% tiger nut milk, T3= Spreadable processed cheese with 20% tiger nut milk, T4= Spreadable processed cheese with 30% tiger nut milk.

TABLE 6. Effect of partial substitution of water with different levels of tiger nut milkon sensory evaluation of SPC samples.

Parameters	Storage period (days)	Experimental treatments SPC samples with tiger nut milk			
		T1	T2	T3	T4
Appearance	0	$8.50^{a}\pm0.71$	$8.60^{a}\pm0.52$	$8.60^{a}\pm0.52$	$8.70^{a}\pm0.48$
	30	$8.50^{a}\pm0.52$	$8.60^{a}\pm0.52$	$8.60^{a}\pm0.52$	$8.70^{a}\pm0.48$
	60	$8.60^{a}\pm0.52$	$8.70^{a}\pm0.48$	$8.70^{a}\pm0.48$	$8.80^{a}\pm0.42$
Color	0	$8.50^{a}\pm0.53$	$8.50^{a}\pm0.53$	$8.60^{a}\pm0.52$	$8.60^{a}\pm0.52$
	30	$8.50^{a}\pm0.85$	$8.60^{a}\pm0.52$	$8.60^{a}\pm0.52$	$8.70^{a}\pm0.48$
	60	$8.60^{a}\pm0.84$	$8.80^{a}\pm0.42$	$8.80^{a}\pm0.42$	$8.90^{a}\pm0.32$
Flavour	0	$8.50^{a}\pm0.53$	$8.60^{a}\pm0.52$	$8.60^{a}\pm0.52$	$8.70^{a}\pm0.48$
	30	$8.40^{a}\pm0.52$	$8.50^{a}\pm0.53$	$8.70^{a}\pm0.48$	$8.70^{a}\pm0.48$
	60	$8.60^{a}\pm0.84$	$8.80^{a}\pm0.42$	$8.90^{a}\pm0.42$	$8.90^{a}\pm0.42$
Creaminess	0	$8.30^{a}\pm0.67$	$8.40^{a}\pm0.70$	$8.50^{a}\pm0.70$	$8.50^{a}\pm0.53$
	30	$8.40^{a}\pm0.52$	$8.50^{a}\pm0.53$	$8.50^{a}\pm0.52$	$8.50^{a}\pm0.53$
	60	$8.50^{a}\pm0.52$	$8.70^{a}\pm0.48$	$8.70^{a}\pm0.48$	$8.80^{a}\pm0.42$
Firmness	0	$8.30^{a}\pm0.48$	$8.30^{a}\pm0.48$	$8.40^{a}\pm0.52$	$8.60^{a}\pm0.52$
	30	$8.40^{a}\pm0.52$	$8.40^{a}\pm0.52$	$8.50^{a}\pm0.853$	$8.60^{a}\pm0.52$
	60	$8.50^{a}\pm0.52$	$8.50^{a}\pm0.52$	$8.60^{a}\pm0.62$	$8.60^{a}\pm0.62$
Spreadability	0	$8.20^{a}\pm0.63$	$8.30^{a}\pm0.65$	$8.50^{a}\pm0.53$	$8.60^{a}\pm0.52$
	30	$8.50^{a}\pm0.53$	$8.50^{a}\pm0.53$	$8.60^{a}\pm0.52$	$8.80^{a}\pm0.42$
	60	$8.30^{a}\pm0.48$	$8.40^{a}\pm0.52$	$8.60^{a}\pm0.52$	$8.70^{a}\pm0.48$
Overall Impression	0	$8.60^{a}\pm0.52$	$8.60^{a}\pm0.52$	$8.70^{a}\pm0.15$	$8.70^{a}\pm0.15$
	30	$8.40^{a}\pm0.52$	$8.40^{a}\pm0.70$	$8.60^{a}\pm0.52$	$8.80^{a}\pm0.42$
	60	$8.10^{b}\pm0.32$	$8.50^{a}\pm0.53$	$8.70^{a}\pm0.53$	$8.90^{a}\pm0.48$

* Results are expressed as Mean ± SD; means with different superscripts in a row differ significantly (p □0.05). T1= Spreadable processed cheese without tiger nut milk, T2= Spreadable processed cheese with 10% tiger nut milk, T3= Spreadable processed cheese with 20% tiger nut milk, T4= Spreadable processed cheese with 30% tiger nut milk.

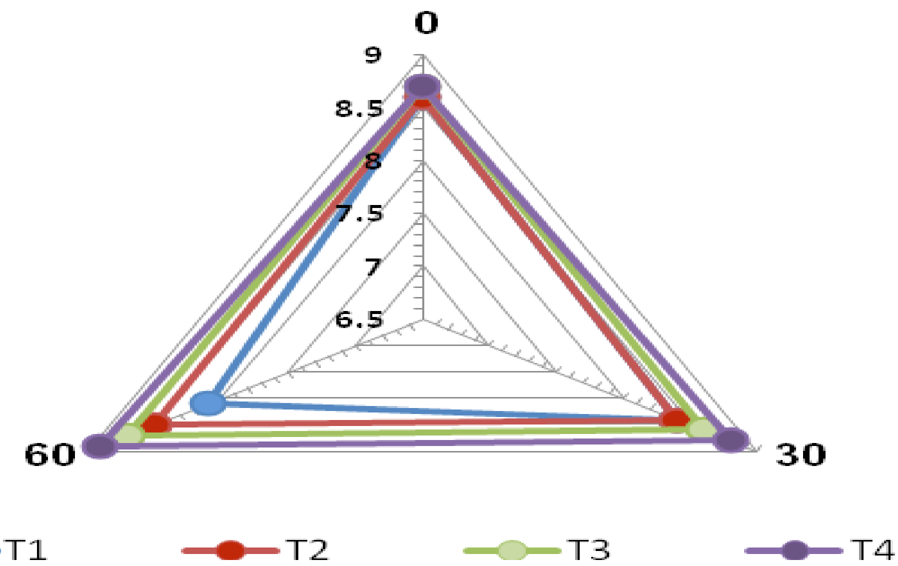

Fig. 3. Overall impression of SPC samples during storage periods.

Conclusion

Tigernut milk (TNM) improved the physicochemical properties of SPC with a higher impact at the high level of used milk. SPC treated with higher level of TNM contained higher phenols and antioxidant activities in comparison to the SPC sample free from TNM. In addition, TNM enhanced the physical properties of SPC samples. Higher meltability was observed in SPC sample with higher level of TNM, while TNM reduced the separation of oil from SPC samples during storage. TNM enhanced the fatty acid profile of SPC samples, higher oleic and linoleic acids were detected in SPC samples with higher level of TNM. In addition, SPC samples with TNM had no growth of microorganisms during the period of storage and SPC samples were free from yeast and molds and coliform bacteria. SPC samples with TNM had the higher sensorial scores when compared to SPC without TNM. TNM could be used up to 30% in the production of SPC with acceptable quality attributes.

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